CNES Proposal Cover Sheet

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Proposal No.

Title: SEASONAL TO INTERANNUAL VARIABILITY OF THE ATLANTIC NORTH-EASTERN TROPICAL UPWELLING SYSTEM (ANETUS) : LOOKING FOR CAUSES AND BASIN-SCALE CONSEQUENCES

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III. IDENTIFYING INFORMATION

SEASONAL TO INTERANNUAL VARIABILITY OF THE ATLANTIC NORTH-EASTERN TROPICAL UPWELLING SYSTEM ANETUS : LOOKING FOR CAUSES AND BASIN-SCALE CONSEQUENCES

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IV. INVESTIGATION AND TECHNICAL PLAN

IV.1 Summary

The aim of the present proposal is to improve the understanding and modelling of ocean and coupled ocean-atmosphere variability in the tropical northern Atlantic at seasonal-to-interannual time scales. To achieve that goal, we are interested in focusing our effort on multi-captor satellite data to study the eastern half of this sub-basin through its relation to the African Monsoon and the Atlantic Inter-tropical Convergence Zone complex.
Unlike within the much larger Pacific ocean, the northern tropical upwelling zone of the Atlantic commonly referred to as the ensemble made of the coastal Mauritania-Senegal upwelling and the off-shore Guinea Dome upwelling, occupies an important fraction of the basin longitudinal extension. The overlying atmosphere planetary boundary layer displays major annual and interannual variations associated to African monsoon developments, which are likely to be coupled to the upwelling system cycle. This eastern system is furthermore extended by a large scale, open ocean upwelling region during summer and fall, associated with the marine Inter-Tropical Convergence Zone complex. This western extension is forced by overlying trade wind curl but likely, also by Rossby waves that emanate directly from the easternmost upwelling zone. This basin scale ensemble forms the Atlantic North-Eastern Tropical Upwelling System: the ANETUS.
Our proposed study is to describe and better understand the annual to interannual variations of oceanic and atmosphere conditions in the vicinity of the ANETUS and those to the west resulting from Rossby wave propagations. Using satellite data, the sea surface height , sea surface temperature, wind and precipitations will be analyzed. These remote sensing data will be complemented by synchronous in situ measurements (PIRATA, Argo floats), and other observational and reanalysis products. In parallel, simulations from various model configurations will be used for an optimal depiction and comprehension. A large part of the effort will be aimed at a better understanding of the physical bonds between the ANETUS three-dimensional processes and their remotely measurable surface signatures. In parallel, attention will be paid to the role of the local atmosphere forcing on the ANETUS and Air-sea-land coupling implications, as well as the more westerner oceanic consequences of the eastern variability. To this goal, ocean model sensitivity studies will be conducted. Selected synoptic to seasonal and interannual patterns of atmosphere forcing associated to African monsoon and Inter-Tropical Convergence Zone (ITCZ) will be imposed. Such experiments will underscore the sensitivity of this system to local atmosphere variability. In parallel, the subsequent anomalous signals propagating westward as first baroclinic Rossby waves will be analyzed in order to estimate their potential impact on oceanic conditions to the west, and particularly in the vicinity of the climate key actor which is the Atlantic Marine ITCZ.

IV.2. Experimental objectives

1. General objectives

The tropical Atlantic climate is currently a particularly challenging issue for the climate research community. It has been established as a dominant climate signal in the northern hemisphere (Marshall et al., 2001) with major socio-economics impacts, but its variability lacks severely of sufficient understanding; consequently, most climate models are simulating reverse SST gradients and monsoon winds in the region (Davey et al., 2002). Such a scientific challenge is due on one part to the complexity of a region where numerous atmosphere, oceanic and land processes are interplaying at the scale of the basin, and on the other part because the Atlantic received much less attention during the last decade than the Indo-Pacific basin.
The overall objective of our proposal is therefore **to bring a set of new information, linking ocean /atmosphere three-dimensional dynamics with satellite surface measurements**, on the **Atlantic North Eastern Tropical upwelling system** (the

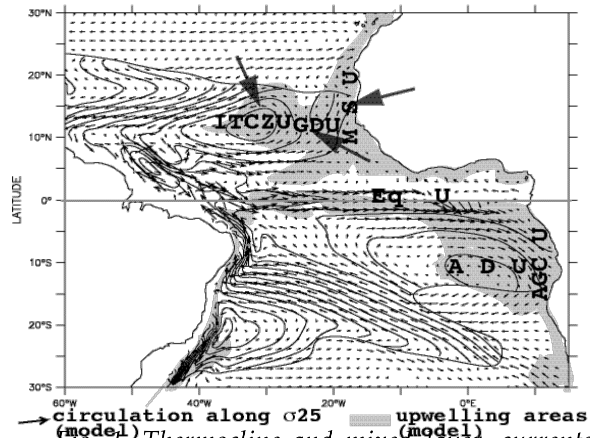


Fig. 1. Thermocline and mixed layer currents (arrows and streamlines), and main upwelling zones of the tropical Atlantic in annual mean : ITCZ, Guinea Dome, Mauritania-Senegal, Equatorial, Angola Dome and Angola-Gabon-Congo.(based on Siedler et al., 1992 and Lazar et al., 2002). The three pointed upwelling zones form the ANETUS

ANETUS, Fig. 1). The elements of the ANETUS can be distinguished based on their forcing mechanism: a) the intense coastal Mauritania-Senegal upwelling associated mainly to the along shore component of the trade winds, b) the Guinea Dome upwelling associated to a local seasonal open ocean wind curl (Siedler et al, 1992), and c) the large scale open ocean upwelling associated to the curl of the wind field of the AMI (Inui et al., 2001) which extends seasonally far to the west. **We are interested with this physical system for several reasons**. Firstly, the eastern tropical upwellings form, within the Atlantic, North or South, **the regions thermodynamically the most active** where the seasonal and interannual SST variations are from far the largest (the standard deviation of the Mauritania Senegal upwelling is the largest of the whole tropical Atlantic; not shown), in large part due to the extremely shallow underlying thermocline. Secondly, this is where **the lack of in–situ observation is the highest**, the understanding being consequently very poor. Thirdly the **ocean and atmosphere models have large systematic biases** over these regions. Fourthly the northern tropical sub-basin **shelters the whole seasonal migration of the Atlantic Marine ITCZ** (AMI) as well as the African Monsoon, which movements control the precipitation and Climate over the tropical Atlantic land masses. Also, in the context of the joint US-France JASON research announcement, a dedicated study on the north-eastern tropics will constitute a companion study to the nationwide initiative on this region launched by US researchers during a series of recent ocean-atmosphere workshops (in particular: "Effect of atmosphere forcing and upper ocean teleconnections on tropical Atlantic SST variability" at the Univ. Maryland, 2002). Lastly, the ANETUS beeing a **major system for the Atlantic marine resources**, it became recently the focus of research programs in coastal oceanography and bio-geochemistry: a) the Institut de Recherche pour le Développement (IRD) recently started the high resolution simulation of the coastal part of the ANETUS (Marchesiello, 2002) which will provide an unprecedented flow of numerical data useful for the interpretation of observation in the region, in particular satellite data; b) M. Levy, through a TOSCA proposal, is starting the bio-geochemical study of the system. The interactions between these two programs and ours should be extremely fruitful.

For the understanding of the ANETUS, its causes and impacts, a major advantage of SSH over other variables estimated by satellites (SST, Chlorophylle) is its direct link with the dynamics at play in the upwellings. SSH anomalies are precisely the expected surface signals of an upwelling, whereas anomalies of SST or Chlorophylle are complex consequences of the former and numerous other factors. **SSH is therefore the more natural variable to use** for interpretation and understanding of the ANETUS ocean dynamics. In consequence, the investigators of this proposal plan to study the ANETUS by first describing, analyzing and understanding the climatological characteristics of the system (§2). Then its variability, at interannual time scales, will be studied in light of the climatological properties (§3). In parallel, the importance of the wave processes will be particularly addressed in terms of local as well as remote activities (§4).

2. The climatological spatio-temporal patterns of the ANETUS and the associated atmosphere structures.

Whereas the subduction processes characterizing a major part of the subtropics and the tropics have benefited of considerable attention, the upwelling processes at the surface boundary of the oceanic circulation are not well known. The ANETUS encompasses three upwelling regions that interact together, and their specific spatial distribution, seasonal to interannual variability remain to be described and analyzed using long-term satellite, in situ and model data (e.g., Carton and Zhou, 1997, Lazar et al., 2002), in particular in the perspective of their mutual interactions, that form the basin scale ANETUS. Hence one of the major objective of this study is to establish a clear link between surface signature as seen by remote measurements of SSH, and SST anomalies and 3-D oceanic patterns through observations and model data analyses.

Preliminary results from model simulation indicate promising results for the ANETUS regarding links between upwelling and SSH at seasonal timescale (not shown). The physical basis for the SSH/upwelling primary relationship is evidently the impact of the wind curl in the Ekman layer but, more in detail, particular attention should be paid to mixed layer evolution and content of heat, salt and mass, in light of surface fluxes, entrainment processes and horizontal advection observation-derived estimations (as in Foltz et al., 2003a,b) and model calculations (Lazar and Servain, 2003). Similarly to the coastal upwelling processes, one expects the temperature and salinity gradient to be maintained by eddy heat fluxes limiting the mean, wind-driven, upwelling cold advection. Regarding the surface projections of the ANETUS, their understanding passes through the analysis of both SSH and Eddy Kinetic Energy (EKE) signals (Marchesiello et al., 2003). The decay to the west of the altimetric surface EKE signal in the coastal transition zone is

important and was attributed to damping by vertical mixing (e.g., McCreary et al., 1991). Haney et al. (2001) suggest an alternative mechanism where EKE generated during the upwelling season from baroclinic instabilities spreads downward via a transformation into barotropic currents. The issue of a decomposition of the SSH variability signal into its baroclinic and barotropic components is of interest and the high resolution modeling of the coastal upwelling will contribute to address the question.
In upwelling regions, when activity strengthens, the colder SST strongly reduces the convective activity, resulting in a thinner, very stable and almost tight mixed layer. The top of this atmosphere boundary layer generally corresponds to the top of the cloud cover (stratiform clouds, shallow convection clouds). The stratiform clouds tend to cool the SST (Yu and Mechoso, 1999; Gudgel et al., 2001), which probably leads to some ocean-atmosphere retroactions at the seasonal to interannual timescales (Oreopoulos et al., 1993). Because of the very thin depth of the inversion layer at the top of the boundary layer, atmosphere global models (as NCEP and ECMWF) fail properly simulating such structure, leading to an excess humidity in the upper atmosphere. Thus, the low atmosphere layer, and in particular its variability at the different spatial and temporal scales, will be analyzed using the satellite and in situ data: atmosphere boundary layer height, given by the temperature at the top of the cloud cover (obtained with the infrared radiometer), via the hydrostatic equation (Mathieu et al. 2003); integrated humidity (SSM/I, TMI) which is strongly correlated with the humidity in the boundary layer; surface winds from scatterometers (Quikscat, SSM/I, altimetric data); and surface fluxes (Meteosat, see Weill et al. 2003) and SST (TMI, AVHRR)

3) Interannual variability.
After a climatological seasonal cycle study, the interannual modulations will be studied, and linked to important climate extremes, like the impact of strong ENSO (i.e. 1997-98) or strong Atlantic inter-hemispheric or equatorial mode (i.e., 1984). Such a study is very promising since one dominant pattern of air-sea interaction, the inter-hemispheric mode (Servain, 1991; Melice and Servain, 2003), shows clearly a interannual variability SST tropical north-eastern center of action that coincides with the spatial extension of the ANETUS (not shown). These similarities are better understood if one realize that the ocean and the atmosphere are strongly coupled through the atmosphere boundary layer in the Tropics. This is particularly visible when comparing eastern tropical upwelling extensions and the AMI internannual variability patterns (Kushnir et al., 2003). Importantly for our project, a recent study by Ayina and Servain (2003) suggests that the SSH/upwelling link still clearly emerges at interannual to decadal frequency.

4) Wave processes within the ANETUS and their remote sources and impacts
The variability of the upwelling is primarily due to mesoscale geostrophic currents, and the mesoscale synoptic structure is a combination of upwelling fronts, offshore squirts and filaments, and eddies. The eddies provide an important dissipation mechanism for the mean circulation through instabilities.
The ANETUS region, particularly in its eastern part, shelters an intense wave activity associated with Kelvin, Rossby, internal-gravity and tropical-instability waves (TIW). This proposal intends to cover in detail the first three types of wave. Since it has been hypothesized that TIW activity characterizes the equatorial region as far as 10°N (Foltz et al., 2003), we acknowledge this possibility through a collaboration with F. Marin, co-PI of a dedicated JASON proposal to TIWs ("tropical instability waves observations and causes" by Marin and Menkes).
Regarding the planetary waves in the vicinity of the ANETUS, it was shown that similar eastern upwellings are characterized by seasonal westward propagation for SSH and for surface and depth-integrated EKE (Marchesiello et al., 2003). The speed is about what is expected from baroclinic Rossby waves, as pointed out in observational analyses (e.g., Chelton & Schlax, 1996). However, while it is generally admitted that baroclinic Rossby waves are generated along eastern boundaries, the precise mechanisms by which this is achieved are still largely unknown. Yet, a basic theoretical understanding of these mechanisms is required if we are to understand the nature and importance of the remote response potential achieved by the westward propagating signals observed in the SSH, SST, and sea surface color. So far, two main theoretical mechanisms for the generation of baroclinic Rossby waves have been proposed. The first one (White, 1977) argues that baroclinic Rossby waves are generated along the eastern boundary because the background geostrophic mean circulation is unable to satisfy the no-normal flow condition on its own, the amount of the waves generated being then what is required to enable the latter boundary condition

to be satisfied. Another theoretical mechanism that has been invoked argues that Rossby waves are generated by the radiation of coastal (Kelvin) waves (Millif and McWilliams, 1994; Grimshaw and Allen 1988; McCalpin 1995). Even though equatorial and open ocean Rossby wave propagations are clearly established in SSH and SST satellite observation (in particular by collaborators to the project: França et al., 2003; Dandoneau et al., 2003), the validity of the above mechanisms is still under debate. One reason is that resolving correctly the physical processes associated with the generation of baroclinic Rossby waves by the upwelling systems requires resolving the Rossby radius of deformation, which is still out of reach of most current General Circulation Models. This will be possible in this project through the use of ROMS, whose spatial resolution appears to be sufficient to resolve the relevant physical processes. Recent work by Florenchie et al. (2003) demonstrates the major role of equatorial and coastal wave dynamics in the remote control of the mixed layer depth and SST anomalies at interannual time scale in the Atlantic southeastern tropical upwelling. It is likely that comparable processes are at play within the ANETUS. However, the more complex shape of the coastline between the equator and the ANETUS calls for specific analysis of this region. In this project, we will attempt to quantify both empirically and theoretically links that we know must exist between: 1) the wind forcing along the eastern boundary, 2) the structure of the upwelling system, 3) the structure of the mean geostrophic circulation along the eastern boundary 3) the amount of coastal waves generated, 5) the amount of baroclinic Rossby waves generated, 6) the diabatic response and heat budget of the upwelling system. In order to make comparisons with satellite observations, we will attempt to determine the expected theoretical signatures of the above elements in the surface.
Regarding inertia-gravity waves in the vicinity of the ANETUS, We shall investigate their dynamics and its role during adjustment processes of upwelling fronts, demonstrated to be fundamental in laboratory experiments and idealized numerical simulations (Bouruet-Aubertot and Echevin, 2002; Bouruet-Aubertot and Linden, 2002). These waves have spatial and time scales smaller than planetary waves and can play a role in dispersing the available potential energy of the upwelling system. Moreover, breaking internal waves contribute to the mixing in the thermocline and at the base of the mixed-layer (Bouruet-Aubertot et al., 2001). Here we propose to analyze in situ data and high-resolution simulations (ROMS) with the aim of quantifying the amount of the observed variability explained by the internal wave field and interactions with larger scale motions. The analysis of simultaneous atmosphere forcings and of circulation features like propagating Rossby waves and mesoscale features, as observed in simultaneous altimetric SSH data and satellite SST (e.g. Iudicone et al., 1998; Buongiorno-Nardelli et al., 1999), will allow to define the sources of the internal wave variability and to identify their links with the upwelling activity. In parallel, idealized domain high-resolution simulations will be performed as a complement of the data analysis.

IV.3. Approach

The team gathered for this proposal is constituted by an ensemble of expert in various fields relating to the very specific issues we developed above. Multi-captor satellite and in situ observations will be interpreted through the use of ocean and atmosphere numerical models as well as theoretical models. In the following we present the various tools and techniques we propose to use to reach our experimental objectives. Models, data, and analysis methods to be used are presented.

1. MODELLING:

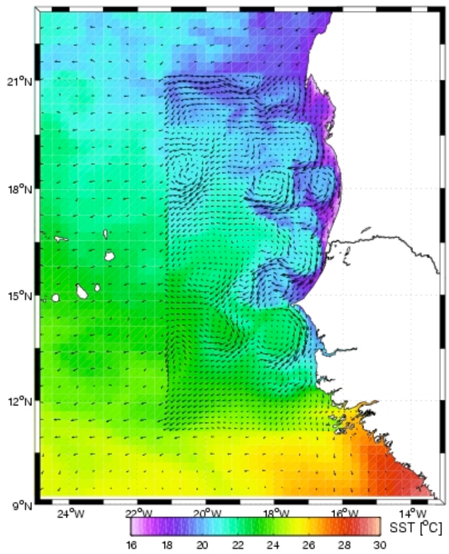
The use of ocean and atmosphere models is a major investigation tool four our purpose of linking satellite measurable signals to 3-D ocean and atmosphere variables of the ANETUS. It is a powerful way to interpret the satellite and *in-situ* observations and assemble together in a synthetic picture of the phenomenon. For a given target phenomenon, we will identify the key-processes in the simulations and systematically establish, as soundly as possible in terms of physical mechanisms, what are their surface signatures in term of SSH and SST. This is thus the modelling studies that will provide new learnings for the physical interpretation of the data.

<u>The OPA ocean general circulation model: configurations ORCA2, ORCA05.</u>

The OPA model physics has demonstrated its ability in simulating surface and subsurface temperature, salinity and currents, in particular within the tropics. In particular OPA has a free surface (Roullet and Madec, 2000) particularly adapted to the resolution of SSH signals. We have confidence, and experience, in using this model to further investigate the dynamical and thermodynamical processes involved in ocean and coupled ocean-atmosphere processes associated with the ANETUS. The two global (2x2 degree horizontal resolution, 30 horizontal levels) and ORCA05 (same as ORCA2 but with a 0.5x0.5 degree horizontal resolution) configurations have been successfully ran at LODYC by G. Madec (collaborator of this project), both in climatological and interannual mode. Later in the project, we will set up a high resolution (less than a degree on the horizontal) idealized square sub-basin based on OPA, and aimed at understanding small scale wave processes in open ocean upwellings (the Guinea Dome upwelling and the AMI upwellings).

The High Resolution Ocean model ROMS of the Coastal upwelling region.

As complement to data analysis and large-scale modeling, ANETUS will include a state-of-the-art high-resolution model of the oceanic circulation on the western African coast. To strengthen multi-disciplinary modeling and data synthesis in upwelling studies, and to satisfy the critical need for coast wide unification, a computational research program was started a few years ago at UCLA developing the Regional Oceanic Modeling System (ROMS) to simulate phenomena over entire coastal systems. This model was applied successfully to the California Current System (Marchesiello et al., 2003). P. Marchesiello has now started its application to the Canary Current System in the context of an IRD research program. The configuration for the Canary Current System goes from 5N to 40N with a resolution of 25km. An embedded level at 6 km resolution is implemented in the southern region (Figure 4). At this resolution, the production of unstable flows associated to the upwelling process is already realistic. Filaments are vigorous and able to produce large exchanges of water and material properties between the coastal and offshore areas. As a final step for the reconstruction of the entire coastal upwelling dynamics, bio-geochemical model will be coupled to the physical model. To investigate the full spatial and temporal variability of the upwelling system, the model will be forced with large-scale interannual atmosphere forcing, both local and remote. The latter is transmitted through the regional boundaries and requires the use of large-scale ocean models such as the ORCA-OPA experiments planned in ANETUS.



g. 4. ROMS configuration for the orthern Altantic upwellings system

The High Resolution global atmosphere model LMDZOR and the Global Climate Model of the IPSL

The LMDZOR model is the high horizontal resolution global atmosphere model (192x144x19 grid cells) from the Laboratory of Meteorological Dynamics (Paris, France). It is the high-resolution version of the atmosphere model LMDZ used in the Global Climate Model of the Institut de Pierre Simon Laplace (Paris, France). An interannual run for the period1982-2003 is scheduled by J.P. Boulanger (LODYC, Paris) for the end of 2004. This run will serve as the numerical base for the interpretation of observations and satellite data of the atmosphere in the vicinity of the ANETUS.

2. OBSERVATIONS:

Observations form the reference of our study in terms of validations of the model simulations and analysis results. After a given process has been identified both in model and data, and understood as much as possible, we will try to built products (or indices) from satellite data that can represent as closely as achievable the activity associated to the given 3-D process. The comparison between models and satellite data will be achieved by applying the diagnostics specific to data (see following §). The observations will be

-Altimeter gridded data for SSH (TOPEX/POSEIDON, merged ERS-T/P, Jason-1), SST (TRMM), Wind (ERS, QuickSCAT), Precipitation (SSM/I, TRMM), and water vapor (SSM/I, TRMM, AQUA),

-In situ measurements from the PIRATA data (moorings and cruises: wind, surface fluxes, temperature, salinity, and currents down to 500 m), XBT measurements (1979+), ARGO floats data (5 of them recently launched during a campaign through the Guinea Dome organized by collaborator B. Bourlès, PI J. Turton; 15 others launched during a cruise in 2003 between the Guinea Dome and Angola Dome); data from cruises (French EQUALANT, CITHER), in particular from the next EGEE-AMMA cruise (summer 2005) passing through the Senegal and Guinea Dome upwellings.

-Reanalyses NCEP-2 and ERA 40

-New mixed layer depth climatology developed by Boyer de Montaigut et al. (2003)

3. DIAGNOSTIC TOOLS:

The diagnostics we will utilize have been already applied with success by the various investigators and collaborators of the project.

Analysis tools of the oceanic and atmosphere observations and simulations.

-Model mixed layer heat and salt budget. Detailed complete budget will be compared to local (Foltz et al, 2003) and first order budget study (Carton and Zhou, 1997)

-Instantaneous entrainment rate and annual obduction/subduction rate, comparing Eulerian and Lagrangian methods.

-To study the SST of the ANETUS, we will use the technique developed to follow quantities along lagrangian trajectories by Blanke and Raynaud (1996).

-Open ocean Rossby and coastal Kelvin wave analysis through Hovmüller diagrams, Fourier-Hermite projections, Singular Spectral Analysis, etc…

-Empirical Orthogonal Function (EOF) decomposition, spectral analysis of timeseries.

-The combination of the different observational datasets (long-term and shorter-term satellite data, long-term reanalyses, in-situ data) will be used to develop diagnostic analyses of the possible interactions between the atmosphere circulation associated with the African monsoon variability and the oceanic variables. We will use the classical methods of signal statistical analyses, applied at different timescales, synoptic, intra-seasonal and interannual, in a way consistent with what is proposed for the forced ocean simulations.

-In order to overcome the complexity of the oceanic signal in the Tropical Atlantic, an appropriate way of separating causes and consequences in the air-sea interaction is the use of lead and lag analysis (de Coetlogon and Frankignoul, 2003). Correlation of time series with temporal lags (local oceanic or atmosphere index, or EOF) will then be used, as well as regression of one field onto a time series, or the maximum covariance analysis between oceanic and atmosphere fields (or SVD, see Bretherton et al., 1992). This study will be conducted at a local scale (for example between SST and air humidity, cloud cover, …) as well as at a larger scale (SST and winds, …).

Analysis tools of the wave dynamics

In order to address the above issues, it is first necessary to have some a priori theoretical knowledge of the vertical structure and spectral characteristics of the various interacting modes. From a mathematical viewpoint, the problem can be formulated as understanding the physical properties of the solutions of the linearized equations of motion around a realistic background mean flow and variable topography. This type of analysis has already been initiated in previous works (see references in biblio info for Tailleux), and will be pursued. The purpose of this theoretical analysis is to define a set of vertical modal structures that will serve as a basis for the analysis of the model outputs of ROMS. As a first step, we will assess the relevance of the theoretical modal structures to describe the dynamics of the long baroclinic and costal waves in the model. This will be done by projecting the anomalies for velocity, pressure, and density, upon the theoretical vertical structure, and by performing a spectral analysis of the horizontal part and comparing it with the theoretical predictions for the frequency/wavenumber spectra (i.e., the dispersion relation). We anticipate that there might be some coming back and forth between theoretical analysis and the treatment of the ROMS model output, until one is satisfied that one understands how to isolate the waves from the forced response in the model results. Once this is done, it will become possible to focus on the physical mechanisms controlling the temporal amplitude variations of the waves and forced response in connection with the surface forcing. Again, we shall try to formulate relevant mathematical problems, whose theoretical predictions will be compared with the model results, going back and forth between theory and model results until one is satisfied that understanding has been reached. In so doing, we will systematically try to determine the surface signatures of all the physical processes involved, in order to distinguish what might be observable in satellite data from what is not.

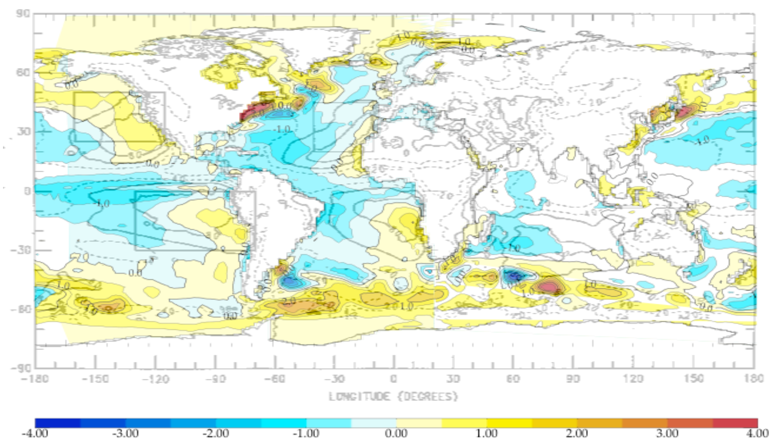
IV.4. Experimental and work plan

In the following, are presented year by year of the project the tasks to complete by the team.

- Year 2004: Climatological cycles :
  1. Analysis of the local 3-D oceanic patterns in models (ORCA2, ORCA05 and ROMS) and observations.
  2. Analysis of the links between local SSH and SST signals and the subsurface
  3. Analysis of the overlying atmosphere patterns, in observations and available forced simulations (LMDZOR) at the time of the study
  4. Begin analysis of the Rossby-Kelvin wave propagations in altimetry, and models.
- Year 2005: Intra-seasonal to interannual variability
  1. Analysis of the 3-D ocean variability (ORCA2, ORCA05, ROMS)
  2. Analysis of the variability in SSH and SST anomalies, link with subsurface
  3. Analysis of the atmosphere interannual variability in satellite, in situ, and model data (LMDZOR)
  4. Begin analysis of internal wave activity based on ROMS and ORCA05
  5. Analysis of the wave propagations in altimetry and model (continued).
  6. Study on the validity of tropospheric correction for altimetric SSH
- Year 2006: Completion and synthesis
  1. Synthesis of the upwelling dynamics and identifications of indexes based on satellite data
  2. Completion of the observational, theoretical and numerical analysis of the wave
  3. Comparison of the ANETUS and the other tropical upwellings signals
  4. Propositions for improvement in tropospheric correction and in ocean model parameterizations

IV.5. Anticipated results

It is anticipated that through these analyses of altimeter data, in situ, and model simulations we will develop a better understanding of the ocean/land/atmosphere processes involved in the activity of the ANETUS. In general we expect to get a better qualitative and quantitative ideas of the links between: 1) the SSH and SST signals, the wind forcing, 2) the structure of the ANETUS system, 3) the structure of the atmosphere circulation and air-sea interactions 4) the amount of Kelvin, Rossby and internal waves generated, 5) and the remote oceanic forcing and impacts. In particular we expect to improve the understanding of seasonal-to-interannual variability of the ANETUS and its link to surface SSH and SST. We will better define the atmosphere structures associated to the ANETUS and the air-sea-land coupled processes in the region with particular focus on the African Monsoon and the Marine ITCZ complex. In this context, we will improve the reliability of the tropospheric correction on SSH satellite measurements. Regarding the ocean dynamics, our study will provide a detailed depiction and better understanding of the wave dynamics as well as water masses transformation associated to upwelling systems in terms of their remote origins and fates. At the basin scale, comparison with the southeastern tropical upwelling system will allow to geographically generalize or restrict our main results. Such a project is expected to produce new insights in the improvement of the physics of numerical climate models. At last, a global warming study will also provide original results regarding longer time scale evolution of the ensemble of major physical processes associated with tropical upwellings and air-sea-land coupling within the tropics.



The ANETUS region, like the other tropical upwelling regions of the Atlantic and Pacific, is characterized by strong errors on SST and ocean color in global ocean model, and by wrong cloud cover and humidity profile in atmosphere models and reanalyses. The frequent occurrence of low stratiform clouds makes difficult to get satellite SST and color from visible / IR sensors, and cloud clearing is often difficult. Furthermore, the atmosphere vertical structure is characterized by a wet boundary layer, often topped by a dry layer (associated with subsidence). The integrated water vapor derived from microwave radiometers is obtained using physico-statistic algorithms, which are adjusted to atmosphere measurements. For those profiles over upwelling areas, which are very far from the mean conditions (statistically), the integrated water vapor content may be poorly retrieved, including systematic biases. In consequence, the SSH, which includes a tropospheric correction derived similarly as the water vapor, may be biased in these regions (for the same reason, the infrared and microwave derived SST are perhaps biased too). In parallel there is no doubt that the ocean models themselves have difficulties in representing with sufficient accuracy the upwelling physics at medium resolution (Fig. 3). We expect that our study of the ANETUS mechanisms and its atmosphere structure will allow us to refine hypotheses aimed at improving satellite-based estimate as well as model physics in the region.

IV.6. Significance of the investigation

Tropical upwelling regions, in particular off equatorial, are oceanic and atmosphere domains characterized by very low in situ observational cover and weak physical understanding. As a major consequence, the link between satellite measurements and local three-dimensional structures is insufficiently known, and errors in atmosphere and ocean simulations are very problematic. Our innovative multi-platform observational and numerical study should amount to important gains in the understanding and simulation of this key region for tropical climate. One of the main particularities of our project is the promising fact that we gathered an international ensemble of scientist experts in satellite data analysis, state of the art climate modeling, as well as in fundamental processes to upwelling physics. The paucity of published worked on the subject advocates for the importance of the present proposal.
Moreover the project will contribute to increase the current state of knowledge in particularly complex disciplinary field like mixing processes due to internal wave effects, air-sea-land coupling, sub-mesoscale non linear processes (e.g. filaments and squirts).
Regarding current and future research and/or operational projects, we particularly underscore the following part of our investigation:
-the opportunity to check the accuracy of retrieved water vapor contents (or tropospheric correction) by comparing with each other the various products available, and with in situ measurements (operational radiosonde data).
-the impact of the West African monsoon on the oceanic dynamics is totally unknown. It is one of the issues of the international program AMMA (African Monsoon Multi-disciplinary Analyses) that is presently under development. Oceanographic campaigns are scheduled for AMMA in 2005, 2006, and 2007 in the Guinean gulf and off the coast of West Africa. This proposal will contribute to analyze the measurements done during these campaigns and will provide the general context in which these short-term campaigns will be conducted.
-the generation mechanisms for the baroclinic and coastal waves are largely unknown at present. Our study should therefore significantly improve our knowledge of these processes. It should also help to determine how to optimize future observational efforts aimed at monitoring the dynamics of coastal areas.
-after having evaluated the link between SSH anomalies and upwelling rate, we should provide an index of coastal and open ocean upwelling activity based on satellite data, especially SSH considering that satellite altimetry has become a fundamental measurement tool in physical oceanography.
During ANETUS, scientists will contribute to the CLIVAR Program, an international research program addressing many issues of natural climate variability and anthropogenic climate change. As part of the wider World Climate Research Program (WCRP) CLIVAR is giving insights into the working of the climate system and hence answers to important questions. As two of the main CLIVAR sub-programs, the CLIVAR Africa and CLIVAR-Atlantic programs address scientific questions related to climate variations on multiple time-scales over the African continent and the adjacent oceans. In addition, the ANETUS is one of the world's most productive areas and its associated fishery is under a large fishing pressure by local and above all not-African fishing companies. International organizations are urging for a scientific management of the marine resources. There is a specific FAO committee, FISHERY COMMITTEE FOR THE EASTERN

CENTRAL ATLANTIC (CECAF/FAO), whose main objectives are to facilitate the coordination of research and to encourage education and training and to assist its members in an advisory management capacity in establishing rational policies to promote the rational management of resources. The functions of the Committee, which has no regulatory powers, are principally to translate and adopt scientifically based conservation recommendations into management measures for adoption.

Also, the EU policy makers have recently declared the area of particular interest for the economic development of both Europe and North Africa. To enhance the responsible exploitation of the ANETUS marine resources, NAT-FISH (Natural variability of a coastal upwelling system and small pelagic fish stocks), a 3-year project (2002-2004) has been funded by the European Commission. It will analyze and quantify the influence of the natural variability of the Northwest African upwelling system on the abundance and distribution of small pelagic fish stocks. It aims at creating an information system, which incorporates environmental monitoring into predictive analysis of the status of fish resources for early inclusion in responsible fisheries management.

By providing insight on the upwelling system dynamics, ANETUS could fuel the above fishery programs by providing information on the physical mechanisms involved in the variability of the productivity and by improving monitoring capabilities (e.g. better upwelling indexes)

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V. MANAGEMENT PLAN AND COST PLAN

V.1. Management plan

-Management of the investigators:
The present proposal gathers several scientists from various international institutes with complementary expertise. For details, please read the bibliographical informations thereafter. As a summary, and in alphabetical order, the investigators are
P. Bouruet Aubertot, an expert of internal waves dynamics and associated mixing and of small scale dynamics of upwellings. She has a wide experience on both in situ and laboratory experiments as well as in numerical models.
G. de Coetlogon, a specialist of ocean-atmosphere interactions in data and models, is an expert in statistical analysis of large ensemble of data.
L. Eymard, expert in the atmosphere boundary layer, in charge of the in-flight calibration / validation and retrieval algorithms of the ERS 1/2 and ENVISAT microwave radiometers, she has recently worked on the long term stability and calibration of TOPEX/Poseidon and ERS microwave radiometers
D. Iudicone, is specialized in ocean mesoscale variability inferred from satellite (altimetry and AVHRR SST) and is a modeler expert in Lagrangian analysis of oceanic circulation
S. Janicot, meteorogist, specialist of tropical climatology and the African Monsoon, expert in data and model analysis
A. Lazar is a modeler, specialized in thermocline / mixed-layer properties and exchanges, and tropical interaction with the atmosphere, he works also on seasonal climate ensemble prediction and Climate Change problems
P. Marchesiello is a modeler, expert in upwelling, regional and coastal physical oceanography, he is specialized in interactions between oceanic domain,,coastal regions, environment, ecosystems, and atmosphere.
R. Tailleux is a theoretician expert in Upper Ocean and atmosphere processes, in particular planetary waves, he works on the improvement of atmosphere and ocean model parameterizations.

J. Servain, physical oceanographer, is the head of the PIRATA network, he is an expert in model and data analysis of the tropical Atlantic and its variability
I. Wainer, is specialized in ocean-atmosphere processes study based on satellite, in situ and model data, she is an expert in Atlantic Climate and Climate Change.

The specific research actions of the above investigators will be dedicated to the experimental objectives according to the following organization:
1- Observed and simulated oceanic data will be retrieved/produced and analyzed by A. Lazar, P. Marchesiello, G. De Coetlogon, J. Servain, and D. Iudicone
2- Observed and simulated tropospheric phenomena (winds, fluxes) will be retrieved, compared, validated and analyzed by G. De Coetlogon, S. Janicot, and L. Eymard.
3- Atmosphere simulations will be analyzed by G. De Coetlogon, A. Lazar, and S. Janicot
4- Theoritical, observational, and numerical analyses of wave dynamics will be handled by R. Tailleux, P. Bouruet-Aubertot, I. Wainer and A. Lazar
5- At different stages of the proposal, graduate students will contribute to the validations and analyses.

Request: A PhD student or a postdoctoral student is strongly desired to contribute to the collect and the analysis of the ensemble of information gathered on the ANETUS.

-Collaborators:
The ANETUS project depends also on the expertise of the following renowned scientists, to whom the PI's will regularly present the progress of the project:
-Research Director Sabine Arnault, physical oceanographer at LODYC, is a specialist of the analysis of SSH signals from satellite measurements.
-Researcher Marina Levy, bio-chemical oceanographer at LODYC, will study the ANETUS in term of geochemical fluxes as the PI of a CNES supported research project. Regular interactions are scheduled between the two projects.
-Resarch Director Gurvan Madec, physical oceanographer, is the head of the modeling team at LODYC, he is an international expert on ocean modeling.
-Senior resarcher Bernard Bourlès, physical oceanographer, is in particular the head of the national observational program EGEE on the Gulf of Guinea and its surroundings, a program associated to the international AMMA project on African Monsoon. He is an expert in in-situ observations acquisition and analysis, and is currently working on getting new data within the ANETUS region.
-Professor Antonio J. Busalacchi, a physical oceanographer, is expert in satellite observations analysis and assimilation, climate modeling, and tropical air-sea coupling processes. He is in particular the co-chair of the CLIVAR Science Steering Group. We will enhance our collaboration, started during the postdoctoral stay of A. Lazar at the ESSIC, Univ. of Maryland.
-Research director Yves du Penhoat is a physical oceanographer, expert in satellite and in situ observations, more particularly for the tropical Atlantic and Pacific.
-Professor Paola Malanotte Rizzoli, a physical oceanographer, is an expert in satellite observations assimilation. We will enhance our collaboration started during the postdoctoral stay mentioned above.
-As developed in the text, the ANETUS region southern boundary coincides with the northern boundary of the JASON project on TIWs by Frédéric Marin. We will ensure a close collaboration with him in order to exchange results, in particular on the subject of westward propagation of planetary waves.

-Science steering:
In order to foster collaborations within the co-investigators and the collaborators, we will organize a yearly workshop with as many of the actors of the ANETUS project as possible. Scientists external to the project, but working on tropical upwelling systems of the Atlantic, the Indian and the Pacific (see Fig. 4) shall also be solicited for participation during additional workshop days.

-Facilities and Equipment
Most of the simulations (without and with assimilation, as well as coupled experiments) will be run at the French National Center For Supercomputer Calculation (IDRIS). The global model is run on the NEC SX 5 supercomputer. `

Request: A powerful workstation (for data processing and visualization) with hard disk is requested.

V.2. Cost plan

Cost categories

Materials:	Publications (6)	=	12k€
	Workstation (graphics) + hard disk	=	5k€
Travel:	missions	=	16,5k€
	Presentations at international meetings (4)	=	8k€
PhD or Postdoctoral student (3 years)		≈	120k€
		=	161,5k€

Detailed cost schedule

Three annual workshops are scheduled for the investigators, they are considered here as missions only for the French investigators, the foreign investigator will ask coverage to their national agencies.

First year:

Workstation (graphics) + hard disk	=	5k€
1 missions Paris <-> Toulouse (PI/coI)	=	500€
2 missions Paris <-> Naples (PI or CoIs)	=	1k€
1 missions Paris <-> Brest (PI or CoIs)	=	500€
1 mission Paris -> Brazil (PI or CoIs)	=	2k€
1 mission Paris <- South Africa (CoI)	=	2k€
PhD or postdoc	≈	40k€

Second year:

1 missions Paris <-> Toulouse (PI/coI)	=	500€
1 mission Paris -> Brazil (PI or CoIs)	=	2k€
2 missions Paris <-> Naples (PI or CoIs)	=	1k€
2 missions Paris <-> Brest (PI or CoIs)	=	1k€
1 mission Paris -> Washington DC (PI)	=	2k€
PhD or postdoc	≈	40k€
2 presentations at an international meeting (PI/CoI)	=	4k€
Publications (3)	=	6k€

Third year:

1 missions Paris <-> Toulouse (PI/coI)	=	500€
1 mission Paris -> Brazil (PI or CoIs)	=	2k€
2 missions Paris <-> Naples (PI or CoIs)	=	1k€
1 mission Paris <- South Africa (PI or CoI)	=	2k€
2 missions Paris <-> Brest (PI or CoIs)	=	1k€
PhD or postdoc	≈	40k€
2 presentations at an international meeting (PI/CoI)	=	4k€
Publications (3)	=	6k€

VI BIOGRAPHICAL INFORMATIONS

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2000-2001: Research Associate, Earth System Science Interdisciplinary Center, University of Maryland.
1997-00: Research Associate, University Space Research Association, NASA-GSFC
1994-95: Research Assistant, French Navy
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Service and Professional Activities:
Member of the Scientific Panel for the Western Extension of the Pilot Research Array in the Tropical Atlantic (PIRATA)
Previously funded proposal:
-Co-principal investigator of the PNEDC 2002-2003 proposal "couplage ocean-atmopsphere dans l'atlantique tropical"
-Co-investigator of the PNEDC 2002-2003 proposal "Variabilité intra-saisonnière à interannuelle du cycle de l'eau de la mousson d'Afrique de l'Ouest »
-Co-investigator of the NOAA proposal in 2001-2003 "Interannual to Decadal Changes in Shallow Tropical/Subtropical Overturning Cells and their Influence on Low-latitude SST in the Atlantic Ocean"
Publications:

T. N. Palmer, A. Alessandri, U. Andersen, P. Cantelaube, M. Davey, P. Delecluse, M. Déqué, E. Díez, F. J. Doblas-Reyes, H. Feddersen, R. Graham, S. Gualdi, J.-F. Guérémy, R. Hagedorn, M. Hoshen, N. Keenlyside, M. Latif, A. Lazar, E. Maisonnave, V. Marletto, A. P. Morse, B. Orfila, P. Rogel, J.-M. Terres, M. C. Thomson, 2003: Development of a European Multi-Model Ensemble System for Seasonal to Inter-Annual Prediction (DEMETER). Submitted to *Bulletin of Meteo. Society*.

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1991-2003: Laboratoire de Météorologie Dynamique (LMD), in the team « Water cycle in the Tropics » (coord. Michel Desbois).
2000-2001: Director of the aeronautical industry-environment market in the "Direction Commerciale et de Communication" at Météo-France (Toulouse).
1982-1991: "Service Etudes et Développement de la Division Climatologie", at Météo-France.
1981-1982: Centre Régional Météorologique du Bourget.
1980-1981: Military Service in the meteorological station in Orly.
1977-1980: Ingeneering Degree, Ecole Nationale de la Météorologie de Météo-France.

Service and Professional Activities:
Meteorology and Tropical climatology
Synoptic to decadal variability of the African Monsoon
Social and economics impacts of the climate variability
Statistical analyses and Signal processing
Climate models
Projects coordinator (PNEDC, AMMA, WAMP)

Recent publications (1998-2003):
JANICOT S., A. HARZALLAH, B. FONTAINE and V. MORON, 1998: West African monsoon dynamics and eastern equatorial Atlantic and Pacific SST anomalies (1970-1988). *Journal of Climate*, **11**, 1874-1882.
FONTAINE B., S. TRZASKA and S. JANICOT, 1998: Evolution of the relationship between near global and Atlantic SST modes and the rainy season in West Africa: statistical analyses and sensitivity experiments. *Climate Dynamics*, **14**, 353-368.
DIEDHIOU A., S. JANICOT, A. VILTARD and P. DE FELICE, 1998: Evidence of two regimes of easterly waves over West Africa and the tropical Atlantic. *Geophysical Research Letters*, **25**, 2805-2808.
DIEDHIOU A., S. JANICOT, A. VILTARD, P. DE FELICE and H. LAURENT, 1998: A fast eastern wave in West Africa troposphere, *Meteorology and Atmosphere Physics*, **69**, 39-47.
DIEDHIOU, A., S. JANICOT, A. VILTARD, P. DE FELICE and H. LAURENT, 1999: Easterly wave regimes and associated convection over West Africa and the tropical Atlantic: Results from NCEP/NCAR and ECMWF reanalyses. *Climate Dynamics, **15**, 795-822.*
FONTAINE, B., S. JANICOT and P. ROUCOU, 1999: Observed and modelled surface variability in the tropical Atlantic region and its rainfall impacts. *Climate Dynamics, **15**, 451-473.*
B. SULTAN and S. JANICOT, 2000: Abrupt shift of the ITCZ over West Africa and intra-seasonal variability. *Geophysical Research Letters*, **27**, 3353-3356.
POCCARD, I., S. JANICOT and P. CAMBERLIN, 2000: Comparison of rainfall structures between NCEP/NCAR reanalysis and observed data over tropical Africa. *Climate Dynamics, **16**, 897-915.*
JANICOT, S. and B. SULTAN, 2001: Intra-seasonal modulation of convection in the West African monsoon. *Geophysical Research Letters*, **28**, 523-526.
CAMBERLIN, P., S. JANICOT and I. POCCARD, 2001: Seasonality and atmosphere dynamics of the teleconnection between African rainfall and tropical ocean surface temperature : Atlantic versus ENSO. *International Journal of Climatology*, **21**, 973-1005.
RIMBU, N., H. LE TREUT, S. JANICOT, C. BORONEANT and C. LAURENT., 2001: Decadal precipitation variability over Europe and its relation with surface atmosphere circulation and sea surface temperature. *Quarterly Journal of Royal Meteorology Society, **127**, 315-330.*
JANICOT, S., S. TRZASKA and I. POCCARD, 2001: Summer Sahel-ENSO teleconnection and decadal time scale SST variations. *Climate Dynamics*, **18**, 303-320.
DIEDHIOU, A., S. JANICOT, A. VILTARD and P. DE FELICE, 2001: Composite patterns of easterly disturbances over West Africa and the tropical Atlantic: A climatology from the 1979-95 NCEP/NCAR reanalyses. *Climate Dynamics*, **18**, 241-253.
DIEDHIOU, A., S. JANICOT, A. VILTARD and P. DE FELICE, 2002: Energetics of easterly disturbances over West Africa and the tropical Atlantic: A climatology from the 1979-95 NCEP/NCAR reanalyses. *Climate Dynamics*, **18**, 487-500.
SULTAN, B., S. JANICOT and A. DIEDHIOU, 2003: The West African monsoon dynamics. Part I: Documentation of intra-seasonal variability. *J. of Climate*, **16**, 3389-3406.
B. SULTAN and S. JANICOT, 2003: The West African monsoon dynamics. Part II: The pre-onset and the onset of the summer monsoon. *J. of Climate*, **16**, 3407-3427.

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Research Associate

Education:
1987-1990: Engineer of the Ecole Nationale des Ponts et Chaussees (Comp. sci./App. Math)
1989-1990: DEA in Numerical Analysis at University of Paris with honors
1991-1996: PhD thesis at University of Paris, in physical oceanography. With high honors
Research Positions
Jan. 2003 - Today: Postdoc at the University of Cape Town with Chris Reason: study of oceanic and atmosphere teleconnections in the context of improving seasonal forecasting strategies.
Nov. 1999 – Jan. 2003: Postdoc at Laboratoire de Meteo. Dyn. (Paris) with J.Y.Grandpeix (Nov. 2000 to Nov. 2003) and with F. Lott (Nov. 1999 to Nov. 2000). Parameterization of atmosphere deep convection and internal gravity waves drag in AGCMs.
Oct. 1996-Nov. 1999: Postdoc at University of California Los Angeles with J. C. McWilliams. Theory and modelling of baroclinic Rossby waves aimed at interpreting T/P SSH.
Relevant references:
Tailleux, R., and J. C. McWilliams, 2000: Acceleration, creation, and depletion of wind-driven, baroclinic Rossby waves over an ocean ridge. J. Phys. Oceanorg., 30, 2186-2213.
Tailleux, R., and J. C. McWilliams, 2001: Bottom pressure decoupling and the speed of extratropical baroclinic Rossby waves. J. Phys. Oceanogr., 31, 1461-1476.
Tailleux, R., and J. C. McWilliams, 2002: Energy propagation of long extratropical baroclinic Rossby waves over slowly varying zonal topography. J. Fluid Mech., 473, 295-319.
Tailleux, R., 2003a: Comments on: ``The effect of bottom topography on the speed of long extratropical planetary waves''. J. Phys. Oceanogr., 33, 1536-1541.
Tailleux, R., 2003b: A WKB analysis of the surface signature and vertical structure of long extratropical Rossby waves over topography. Ocean Modelling (in press).
Tailleux, R., 2003c: The quasi-nondispersive regimes of long extratropical baroclinic Rossby waves over (slowly varying) topography, J. Phys. Oceanogr., submitted.
Tailleux, R., A. Lazar, and C. Reason, 2003a: Dynamics of density compensated anomalies, Part I: Theory. J. Phys. Oceanogr., to be submitted.
Tailleux, R., A. Lazar, and C. Reason, 2003b: Temperature and salinity signatures of long extratropical planetary waves, J. Phys. Oceanogr., to be submitted.

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Research Interests:
Large-scale, regional and coastal physical oceanography, interactions between oceanic and coastal regions, environment and ecosystems, atmosphere and ocean. Ocean modeling, coupled hydrodynamical and ecosystem models. The dynamics of eastern and western boundary current systems. Upwelling, coastal dynamics, tidal circulation, retention/dispersion processes in bays and estuaries.
Education:
1995: Ph.D. in Geophysical Fluid Dynamics, Universite Joseph Fourier, Grenoble, France.
1990: M.S. at Institut National Polytechnique de Grenoble, France.
Professional Employments:
2003-present: Research Scientist, IRD, Centre de Brest, France.
1998-2003: Research Scientist, IGPP, UCLA, Los Angeles, CA, USA
1995-98: Research Associate, School of Mathematics, UNSW, Sydney, Australia.
Experience at sea:
Coastal cruises around Sydney, Australia, and Los Angeles, California, for observation of physical properties and plankton. Instruments: CTD, ADCP, fluorometer, plankton net, OTV (Ondulating Towed Vehicule).
References:
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Recent publications in peer-reviewed journals:
Marchesiello, P., J.C. McWilliams, and A. Shchepetkin, 2003: Equilibrium structure and dynamics of the California Current System. *Journal of Physical Oceanography*, 33, 753-783.

Caldeira, R.M., and P. Marchesiello: 2002: Ocean response to wind sheltering in the Southern California Bight. *Geophysical Research Letters*, 29 (13), 10.1029/2001GL014563. Highlighted in EOS 83 (37), 10 Sept. 2002.
Marchesiello, P., J.C. McWilliams, and A. Shchepetkin, 2001: Open boundary conditions for long-term integration of regional oceanic models. *Ocean Modelling*, 3, 1-20.
Penven P., J.R.E. Lutjeharms, Marchesiello, C. Roy, and S.J. Weeks, 2000: Generation of cyclonic eddies by the Agulhas Current in the lee of the Agulhas Bank. *Geophysical Research Letters*, 28, 1055-1058.
Marchesiello P. and J. Middleton, 2000: Modelling the East Australian Current in the Western Tasman Sea. *Journal of Physical Oceanography*, 30, 2956-2971.
Marchesiello P., M.T. Gibbs, and J. Middleton, 2000: Simulations of coastal upwelling on the Sydney continental shelf. Marine and Freshwater Research, 51, 577-88.
Das P., P. Marchesiello and J.H. Middleton, 2000: Numerical modelling of tide-induced residual circulation in Sydney Harbour. *Marine and Freshwater Research*, 51, 97-112. Reported in the Sydney Morning Herald, 14 Aug. 2000.
Gibbs M.T., P. Marchesiello, and J.H. Middleton, 2000: Observations and simulations of a transient shelfbreak front over the narrow shelf of Sydney, southeastern Australia. *Continental Shelf Research*, 20, 763-784.
Gibbs M.T., J.H. Middleton, and P. Marchesiello, 1998: Baroclinic Response of Sydney Shelf Waters to Local Wind and Deep Ocean Forcing. *Journal of Physical Oceanography*, 28, 178-190.
Gibbs M.T., P. Marchesiello, and J.H. Middleton, 1997: Nutrient Enrichment of Jervis bay, Australia, during the massive 1992 coccolithophorid bloom. *Marine and Freshwater Research*, 48, 473-478.
Barnier B., P. Marchesiello, A.P. de Miranda, J.M. Molines, and M. Coulibaly, 1998: A sigma-coordinate primitive equation model for studying the circulation in the South Atlantic. Part I: Model configuration with error estimates. *Deep Sea Research*, I 45, 543-572.
Marchesiello P., B. Barnier, and A.P. de Miranda, 1998: A sigma-coordinate primitive equation model for studying the circulation in the South Atlantic. Part II: Meridional transports and seasonal variability. *Deep Sea Research*, I 45, 573-608.

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Assistant professor at the Université Pierre et Marie Curie (Paris VI) since October 2003.
Onward:
Apr. – Sept. 2003: Postdoct, CERFACS / CNRM (Toulouse), "*Extreme events linked with the green-house effect*" (french project *IMFREX*, IMpact des changements anthropiques sur la FRéquence des phénomènes EXtrêmes de vent, de température et de précipitation, coord. M. Déqué). Comparison of the large-scale atmosphere circulation in the North Atlantic / European region in the ERA40 reanalyses; and in 6 numerical simulations of ARPEGE, forced by the SST and radiative forcing in the present (1960-1999) and future (2070-2099) climate.
2002-2003: Postdoc, Laboratoire d'Océanographie DYnamique et de Climatologie (LODYC, University of Paris VI), "*North-Atlantic Oscillation and Gulf Stream interaction*" (European project *PREDICATE*, mechanisms and PREdictability of Decadal fluctuations In Atlantic-European ClimATE, coord. R. Sutton). Analysis of the Gulf Stream variability in 5 Ocean General Circulation Models: comparison with the observations, cross-analysis of the barotropic and baroclinic transports and sea level pressure, study of the gyre adjustment to the atmosphere forcing through the propagation of Rossby waves.
1997-2001: Ph. D. in physical oceanography, LODYC, supervisor: Pr. C. Frankignoul, "Decadal variability in the North Atlantic : re-emergence of sea surface temperature (SST) anomalies and large-scale ocean-atmosphere interactions." Study of the persistence of winter SST anomalies, taking into account the mechanism of re-emergence of the anomalies from one winter to the next in the surface mixed layer. Impact of the advection by the mean currents. Analysis of the interaction between the Gulf Stream and the North-Atlantic Oscillation in the observations (SST Reynolds, NCEP/NCAR reanalyses, Gulf Stream position from the Topex/Poseidon Sea Surface Height).
Education:
April 1999: Oxford/RAL *Spring School in Quantitative Earth Observation* (Oxford University, G.B.)
January 1998: Winter School for Statistical and Mathematical tools in Climate Variability, Ecole de Physique des Houches, France.
1997 (4 months): Training period at LODYC. Supervisor: Pr. C. Frankignoul. Dissertation: "*A simple model of the response of the thermocline to a wind-stress curl forcing*".
1996-1997: Advanced post-graduate degree (DEA) in Oceanology, Meteorology and Environnement, University of Paris VI, specialization: ocean and atmosphere dynamics.
1994-1997: Engineering Degree at the ENSTA, Ecole Nationale Supérieure de Techniques Avancées (Paris). Option: marine environment.
Publications:

De Coëtlogon, G. et al., 2003 : Gulf Stream variability in 5 Oceanic General Circulation Models. To be submitted.
De Coëtlogon, G. et C. Frankignoul, 2003 : On the persistence of the sea surface temperature in the North Atlantic, *J. of Climate*, vol. 16, 9, 1364-1377.
Frankignoul, C., G. de Coëtlogon, T. Joyce et S. Dong, 2001 : Gulf Stream variability and ocean-atmosphere interactions, *Journal of Physical Oceanography*, 31, 3516-3529.
Sirven, J., C. Frankignoul, G. de Coëtlogon et V. Taillandier, 2002 : Spectrum of wind-driven baroclinic fluctuations of the ocean in the midlatitudes, *J. of Phys. Oceanography*, 32, 2405-2417.
Frankignoul, C., E. Kestenare, N. Sennéchael, G. de Coëtlogon et F. d'Andrea, 2000 : On decadal-scale ocean-atmosphere interactions in the extended ECHAM1/LSG climate simulation, *Climate Dynamics*, 16, 333-0354.
Statistical skills:
Regression, statistical significance, Empirical Orthogonal Function (EOF), Maximal Covariance Analysis (MCA), spectral analysis, Multi-Channel Singular Spectrum Analysis (MSSA), decomposition in weather regimes, lead and lag analysis.

Pascale BOURUET-AUBERTOT

Pascale Bouruet-Aubertot is an expert of internal waves dynamics and associated mixing and of dynamics of coastal upwellings. She has a wide experience on both in situ and laboratory experiments as well as in numerical models.

C. Staquet and P. Bouruet-Aubertot, 2001: "Mixing in weakly turbulent stratified flows". *Dynamics of Atmospheres and Oceans*. 34/2-4, pp 81-102.
P. Bouruet-Aubertot, C. Koudella, C. Staquet, K. Winters, 2001: "Particle dispersion and mixing by breaking internal gravity waves", *Dynamics of Atmospheres and Oceans*, 33, 95-134.
C. Staquet, P. Bouruet-Aubertot, C. Koudella, 2000: "Mixing by breaking internal gravity waves". *Turbulent mixing in geophysical flows*, PF Linden and JM Redondo eds, CIMNE pub., Barcelona, pp.177-201.
P. Bouruet-Aubertot, S.A. Thorpe, 1999: "Numerical experiments of internal gravity waves in an accelerated shear flow", *Dynamics of Atmospheres and Oceans*, 29, 41-63.
P. Bouruet-Aubertot, J. Sommeria, C. Staquet, 1996: "Stratified turbulence produced by internal wave breaking", *Dynamics of Amosphere and Oceans*, 23, 371-378.
P. Bouruet-Aubertot, J. Sommeria, C. Staquet, 1995: "Breaking of standing internal gravity waves through two-dimensional instabilities", *Journal of Fluid Mechanics*, 285, 265-301.

Laurence EYMARD

Since 1991, Laurence Eymard is in charge of the in-flight calibration / validation and retrieval algorithms of the ERS 1/2 and ENVISAT microwave radiometers, and she is a JASON PI. She has recently worked on the long term stability and calibration of TOPEX/Poseidon and ERS microwave radiometers.

Eymard, L., C. Klapisz, and R. Bernard, Comparison between Nimbus-7 SMMR and ECMWF model analyses : The problem of the surface latent heat flux, *J. Atmos. Oceanic Technol.*, **6** (6), 966-991, 1989
Eymard, L., L. Tabary, E. Gérard, A. Le Cornec and S.A. Boukabara, The microwave radiometer aboard ERS-1, Part 2 : Validation of the geophysical products, IEEE Trans. *Geosci. Remote Sensing*, **34**, 291-303, 1996.
Obligis E., L.Eymard, et N.Tran : in-flight cal/val of ENVISAT microwave radiometer Proceedings IGARSS, Toulouse, Juillet 2003.
Tran N., E. Obligis , L. Eymard et C. Ruf : comparison of microwave radiometers on a hot reference area. Proceedings IGARSS, Toulouse, Juillet 2003.

Daniele IUDICONE

Has worked on mesoscale variability from satellite (altimetry and AVHRR SST) data, quantification of vertical mixing from in situ data analysis and on the application of lagrangian diagnostics to OGCM outputs.

Iudicone D., A. Perilli, E. Salusti," Cold filament dynamics in Central Tyrrhenian sea", *Ocean Modelling*, 99, 2-5, 1993.
Simone A., S. Zoffoli, D. Iudicone, R. Santoleri, S. Marullo,"Altimeter data analysis of the Antartic circumpolar current", "The Oceanography of the Ross Sea - Antarctica", *Springer-Verlaged.*, 51-67, 1999.
Iudicone D., P. Gerosa, R. Santoleri, S. Marullo, " Sea level variability of the Mediterranean Sea as seen by TOPEX/POSEIDON data", *Journal of Geophysical Research*, 103, 2995-3012, 1998.
Böhm, B. Buongiorno Nardelli, C. Brunet, R. Casotti, F. Conversano, F. Corato, E. D'Acunzo, F D'Ortenzio, D. Iudicone, L. Lazzara, O. Mangoni, M. Marcelli, S. Marullo, L. Massi, G. Mori, C. Nuccio, M. Ribera d'Alcalà, V. Saggiomo, R. Santoleri, Michele Scardif, S. Sparnocchiae, S. Tozzi, S. Zoffoli "SYMPLEX Experiment: first results on oceanic mesoscale dynamics and related primary production from AVHRR and SeaWIFS satellite data and field experiments.", SPIE vol. 3496, pg. 137-148, 1998.
Buongiorno Nardelli B., R. Santoleri, S. Marullo, D. Iudicone, S. Zoffoli, "Altimetric signal and thee dimensional structure of the sea in the channel of Sicily",. Journal of Geophysical Research, 104, C9, 20585-20603, 1999.
Iudicone D., G. Lacorata, V. Rupolo, R. Santoleri, A. Vulpiani; 'Sensitivity of numerical tracer trajectories to uncertainities in OGCM velocity fields', Ocean Modelling 4 (2002), pp. 313-325, 2002.
Artale V., D. Iudicone, R. Santoleri, V. Rupolo, S. Marullo, F. D'Ortenzio, 'The role of surface fluxes in A OGCM using satellite SST. Validation and sensitivity to forcing frequency of the Mediterranean thermohaline circulation', *J. of Geophys. Res.* Vol 107 C8 , 2002.

Jacques SERVAIN

Research Director at Institut de Recherche et de Developpement in Physical Oceanography. Domain of interest: interannual climate variability in the Tropical Atlantic, teleconnections with rainfall in the nearby continents (African Sahel, Brazilian Nordeste), ENSO in the Pacific, and atmosphere circulation in the North Atlantic.

AYINA, L. H., and SERVAIN J., 2003 : Spatio-temporal evolution of the low frequency climate variability in the tropical Atlantic. In press. Interhemispheric Water Exchange in the Atlantic Ocean (Elsevier Oceanographic Series).
KOUADIO, Y., OCHOU D. A., and SERVAIN J., 2003 : Atlantic influence on the rainfall variability in Côte d'Ivoire. *Geophys. Res. Lett.*, Vol. 30, N°5.
MARCHAND P. and SERVAIN J. 2002: The NOR-50: A Tool for Operational Oceanography. *Sea Technology*, Vol. 43, N° 6, June 2002, pp 49-54.
MELICE, J.-L., and SERVAIN J., 2003 : The tropical Atlantic meridional SST gradient index and its relationships with the SOI, NAO and Southern Ocean. *Climate Dynamics*, 20, pp 447-464.
SERVAIN J., WAINER I., AYINA H. L., and ROQUET H., 2000 : A numerical study of the relationship between the climatic variability modes in the tropical Atlantic. *Int. J. Climatol.*, 20, 939-953.
SERVAIN, J., CLAUZET G. , and WAINER I., 2003 : Modes of tropical Atlantic variability observed by PIRATA. *Geophys. Res. Lett.*, Vol. 30, N°5
WAINER, I., G. CLAUZET, SERVAIN J. and SOARES J., 2003 : Time scales of upper ocean temperature variability inferred from the PIRATA data (1997-2000). *Geophys. Res. Lett*. Vol. 30, N°5.

Ilana WAINER

Research Director at the Dept of Physical Oceanography of the Univ. Of Sao Paulo (Brazil)

Wainer, I., A.S. Taschetto, J. Soares, A. P. Oliveira, Ottobliesner, B. and E. Brady. 2003: Intercomparison of heat fluxes in the South Atlantic. Part I: the seasonal cycle. *J. of Climate*, 16, 706-714.
Wainer, I., G. Clauzet, J. Servain and J. Soares, 2003: Time Scales of Upper Ocean Temperature Variability Inferred from the PIRATA Data (1997-2000). *Geophys. Res. Letters*, (in press).
Goes, M. and Wainer, I; 2003: Equatorial Currents Transport Changes for Extreme Warm and Cold Events in the Atlantic Ocean, Geophys. *Res. Letters*, (in press).
Wainer, I. and S. A. Venegas. 2002: South Atlantic multidecadal variability in the Climate System Model. Journ. Climate, Vol. 15, No. 12, pp. 1408-1420.A.S.

VII Letters of endorsement

Letter from A.J. Busalacchi

Letter from P. Malanotte-Rizzoli

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Dr. Alban Lazar
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75252 PARIS Cedex 05
FRANCE

November 5, 2003

Dear Alban,

Thank you for the advance copy of your Jason proposal titled “Seasonal-to-Interannual Variability of the Atlantic North-Eastern Tropical Upwelling System: Looking for Causes and Basin-Scale Consequences”. In support of our previous efforts on related topics I welcome the opportunity to continue our productive collaboration. As you know, Joel Picaut and I had a long history of NASA-CNES funded collaboration on the applications of TOPEX/Poseidon-Jason altrimetry to studies of the tropical Pacific Ocean. Now that Joel is retiring I look forward to extending such applications and collaboration with you in the Atlantic.

Sincerely,

Antonio J. Busalacchi

Antonio J. Busalacchi
Director and Professor
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April 18, 2004

Dr. Alban Lazar
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FRANCE

Dear Alban:

Thank you for the advance copy of your Jason proposal titled "Seasonal-to-Interannual Variability of the Atlantic North-Eastern Tropical Upwelling System: Looking for Causes and Basin-Scale Consequences". In support of our previous efforts on related topics I welcome the opportunity to continue our productive collaboration. I look forward to working with you on the topics you propose.

Sincerely,

Paola Malanotte-Rizzoli
Professor of Physical Oceanography
MIT Director of the MIT/WHOI Joint Program in Oceanography