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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the Consortium (including the Commission Services)	
CO	Confidential, only for members of the Consortium (including the Commission Services)	

Contribution to project objectives – with this deliverable, the project has contributed to the achievement of the following objectives (from Annex I / DOW, Section B1.1.):

N.º	Objective	Yes	No
1	Reduce uncertainties in our knowledge of the functioning of tropical Atlantic (TA) climate, particularly climate-related ocean processes (including stratification) and dynamics, coupled ocean, atmosphere, and land interactions; and internal and externally forced climate variability.	X	
2	Better understand the impact of model systematic error and its reduction on seasonal-to-decadal climate predictions and on climate change projections.	X	
3	Improve the simulation and prediction TA climate on seasonal and longer time scales, and contribute to better quantification of climate change impacts in the region.		X
4	Improve understanding of the cumulative effects of the multiple stressors of climate variability, greenhouse-gas induced climate change (including warming and deoxygenation), and fisheries on marine ecosystems, functional diversity, and ecosystem services (e.g., fisheries) in the TA.		X
5	Assess the socio-economic vulnerabilities and evaluate the resilience of the welfare of West African fishing communities to climate-driven ecosystem shifts and global markets.		X

Main author(s) of this deliverable: Bernard Bourlès (IRD/LEGOS)

Deviation from planned efforts for this deliverable: None to our best knowledge.

Report

Executive Summary

This report is Deliverable 3.2 of the PREFACE project, produced by the work package WP3. WP3 focuses on improving the understanding of the physical processes controlling the mixed layer heat and freshwater balances in the eastern boundary upwelling regions of the tropical Atlantic and in the Gulf of Guinea, by performing observational and model process studies, extending the Atlantic observing system and providing datasets to evaluate regional ocean and atmospheric, and global climate models. This report focuses on an important contribution to variability of the mixed layer balances in those particular regions: local air-sea feedback mechanisms and their impact on interannual climate variability in the tropical Atlantic. It is based on studies of process analyses of air-sea exchanges and feedbacks using in-situ datasets (including specific radio-soundings datasets acquired in the Gulf of Guinea in spring 2014 during the French PIRATA-FR24 cruise) or on products and numerical experiments. This WP3 deliverable presents summaries of achieved or still on-going work (published, in review or to be submitted), which has also been elaborated in close collaboration with PREFACE WP5[1] partners. It contributes to the WP3 goal to investigate local air-sea interaction and ocean feedbacks in frontal regions and the impact of short period wind fluctuations on Bjerknes

[1] WP5: «Joint observations-model comparisons». More information here: http://preface.b.uib.no/about/wp/wp5/

and wind-evaporation-SST (Sea Surface Temperature) feedbacks controlling interannual and longer time scales. The presented results on air-sea interactions may concern all regional studies; thus, the domain of the studies summarised in this report is not limited to frontal regions, but is extended to the whole area of interest for PREFACE. Presented results may also concern processes inducing SST and oceanic mixed layer changes, as these are key parameters for air-sea exchanges.

Main results can be summarised as follows:

- The wind induced near-inertial energy has significant impact on the mixed layer heat content variability. This highlights the need of additional current measurements and time series in the upper tropical Atlantic ocean. In the long-term, a new parameterisation scheme for the near-inertial mixing parameterisation will be proposed that should improve significantly numerical simulations and predictions. This work will contribute to the numerical sensitivity studies and prediction tasks of WP11[2] and will be developed in deliverable D3.3[3].

- In the coastal upwelling areas, the surface wind signal related to the SST intra-seasonal variability appears weak. Along the equator in the west, tropical instability waves contribute to generate surface wind anomalies through the adjustment of the horizontal surface pressure gradient and the modification of near-surface atmospheric stratification. Along the equator in the east, biweekly oscillations increase ocean and atmosphere intra-seasonal variability.

- In the Gulf of Guinea, the SST influences the wind at seasonal scale through a local modification of the pressure gradient (Lindzen and Nigam's mechanism); this impact is significant as far south as 7 to 8°S, and maximal in the equatorial area where there is in addition a fast adjustment of the vertical stratification in the low atmosphere mixed-layer.

- In the Gulf of Guinea, the intra-seasonal wind fluctuations modulates the position of the northern front of the equatorial cold tongue, which induces quasi-biweekly coupled equatorial SST and surface wind anomalies due to the delayed oceanic and atmospheric responses. The latter must therefore be correctly represented in coupled models in order to reproduce a realistic intra-seasonal variability of lower tropospheric winds in the eastern tropical Atlantic.

- In the Gulf of Guinea, non-local planetary boundary-layer schemes appear to better simulate the surface wind pattern and water vapour distribution needed to realistically capture precipitation variability on intra-seasonal to diurnal time scales.

- In the ITCZ region during boreal summer, the SST seasonal tendency has a clear influence on vorticity, divergence and vertical velocity throughout the whole troposphere.

- In interannual numerical simulations, a better representation of the air-sea exchanges can be obtained by computing the evolution of the atmospheric boundary layer temperature and humidity with a marine atmospheric boundary layer model with prescribed winds. This allows to properly assess the sensitivity of the Atlantic Niño to the interannual variability of the equatorial wind work. Results suggest that the interannual variability of the dynamical forcing (versus thermodynamic component) significantly contributes to the Atlantic Niño variability.

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[2] WP11: «Impact of model improvement and systematic error reduction on climate prediction and projection». More information here: http://preface.b.uib.no/about/wp/wp11/

[3] D3.3: «Summary of the observational studies on the impact of near-inertial waves on shaping mixed layer depth and on energy fluxes at the air –sea interface as well as the fluxes from the mixed layer to the deeper ocean», public report.

- Surprisingly, the haline stratification and barrier layers caused by the river runoff may only explain ~10% of the atmospheric induced cooling difference between plume waters and open ocean waters (as deduced from the impact of Amazon & Orinoco Rivers on tropical cyclone induced cooling).

- The solar radiation penetration depends on the chlorophyll concentration; numerical ocean model results suggest that accounting for this effect leads to a surface warming of regions of the tropical Atlantic with high chlorophyll concentrations, with the exception of the main upwelling regions where it leads to a significant cooling of the sea surface.

- The coastal SST bias in the Benguela upwelling region is largely eliminated in high-resolution (e.g., 1/10°) ocean model experiments driven by accurate high-resolution winds (e.g., QuikSCAT).

1: Potential impact of wind generated near-inertial waves on air-sea exchanges

Pillar, H.N. [1], M. Jochum[1] and R. Nuterman[1]

[1] *Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark*

This study is summarised from the paper “Characteristics of Wind-Generated Near-Inertial Waves at the tropical Atlantic PIRATA Array” by Pillar et al., to be submitted to *J Geophys Res Oceans*. This works documents new constraints on the energy flux from the wind to near-inertial currents at the PIRATA mooring array. It also assesses characteristic forcing mechanisms and decay time scales to aid the development of a GCM parameterisation for mixing by unresolved inertial shear. The near-inertial internal waves are principally generated by surface winds, with additional contributions from nonlinear interactions and other minor processes. Model-based estimates of the annual wind power input to the global surface ocean inertial frequencies span the range 0.3-1.4 TW, with significant uncertainty arising from sensitivity to the spatial and temporal resolution of the wind products employed and unresolved processes in the modelled ocean response. Thus, significant uncertainty surrounds the fate of wind generated near-inertial energy in the ocean. Both observational and modelling studies have suggested that the majority of wind generated near-inertial energy is confined to the upper ocean, generating large shear across the mixed layer base. The resulting entrainment can lead to substantial deepening of the mixed layer following storms, with notable impacts on air-sea heat exchange and biogeochemical cycles. This enhanced upper ocean mixing is poorly resolved in climate models.

In this original study, the key characteristics of the inertial activity and wind power input to upper ocean near-inertial currents, by using datasets from 6 of the 18 existing meteo-oceanic moorings of the PIRATA array, have been explored. The study used the long time series of continuous and concurrent high frequency surface wind and near-surface ocean velocity data. The wind power input to near-inertial currents was computed at each mooring, and the key characteristics of the inertial activity and wind power input to upper ocean near-inertial currents were explored. Time-mean near-inertial current speeds at the PIRATA moorings range from 3.6 cms^{-1} to 13.0 cms^{-1} that is consistent with estimates from near-surface drifters (example in Fig. 1 below). Analysis of these data provides new constraints on inertial energy injection and decay in the tropical ocean which are critical for refinement of existing near-inertial mixing parameterisation, due to acute climate sensitivity to turbulence in the tropical thermocline. This study also provides evidence for a robust relation between near-inertial kinetic energy and mixed layer heat content, calls for better constraints on the vertical variation of upper ocean velocity, and highlights the value of furnishing the tropical moorings with additional current meters.

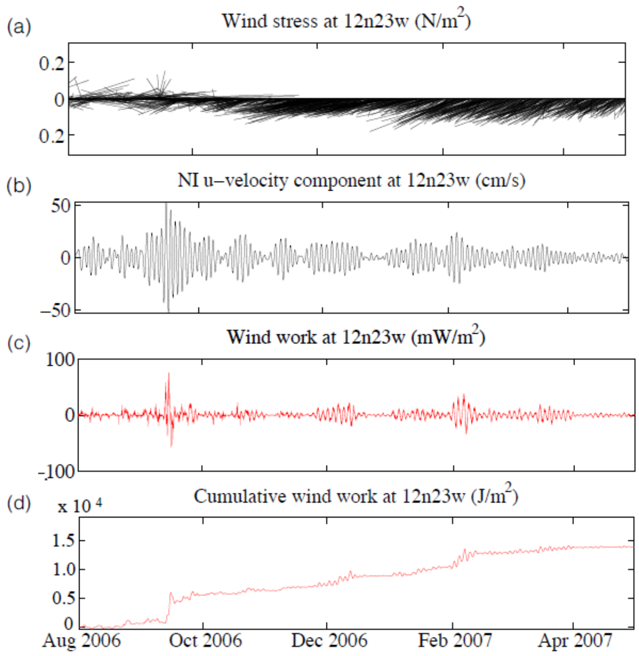

Figure 1: 9 month time series of (a) wind stress, (b) zonal inertial velocity (c) wind power input to ocean inertial currents (WPI) and (d) time-integrated WPI for the PIRATA mooring at 12°N-23°W (Figure 4 of Pillar et al.).

2: Atmospheric responses to SST variations at different time scales

2.1: Air–sea interaction in the Gulf of Guinea at seasonal scale

Meynadier R. [1], G. de Coëtlogon[1], M. Leduc-Leballeur[2], L. Eymard[3] and S. Janicot[3]

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[2] *Laboratoire de Glaciologie et Géophysique de l'Environnement (LGGE), Grenoble, France*

[3] *Laboratoire d'Océanographie et Climat, Expérimentations et Approches Numériques (LOCEAN), Paris, France*

This study is summarised from the paper "Seasonal influence of the sea surface temperature on the low atmospheric circulation and precipitation in the eastern equatorial Atlantic", published by Meynadier et al. in *Clim Dynam* in 2016. Based on satellite observations and WRF simulations forced by different SST patterns, the main goal of this study was to analyse the role of the air–sea interaction in the Gulf of Guinea in setting precipitation at the Guinean coast, during the onset of the West African Monsoon. It clearly shows that the seasonal cold tongue setup, characterised by a very active northern front, strongly constrains the low level atmospheric dynamics between the equator and the Guinean coast. The local SST meridional gradient has noticeable effects on the marine boundary layer stability and hydrostatically-changed meridional pressure gradient, which strongly impacts moisture flux convergence near the coast. Among different results about the processes in play, this study particularly shows (see Fig. 2.1 below), that the SST influences the wind through a local modification of the pressure gradient (Lindzen and Nigam's mechanism). The fast adjustment of the vertical stratification in the mixed-layer is also significant in the equatorial area after the cold tongue onset, but not before, emphasising a threshold effect.

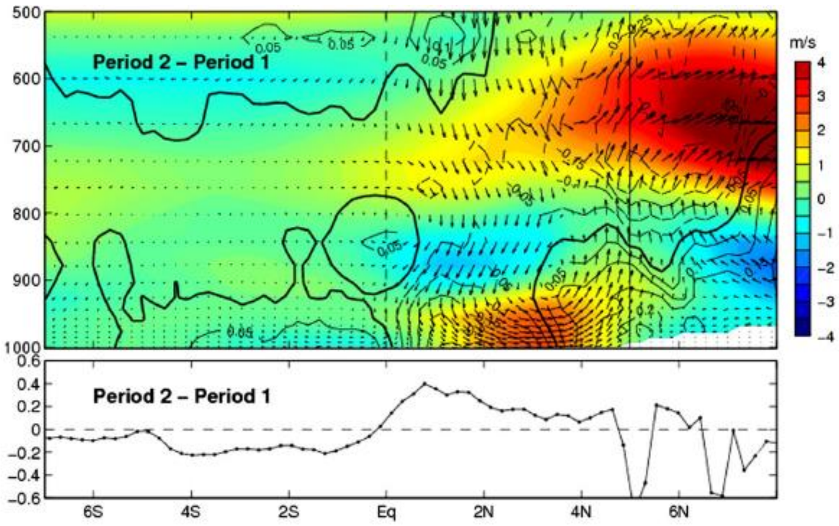

Figure 2.1: Four-weeks composites framing the onset date of the surface wind pattern linked to the equatorial seasonal cooling (late May / early June), 2000-2009, 10°W-0°E. Top: CFSR reanalyses meridional wind (shading, m/s) and meridional gradient of geopotential height (black contours, m / lat. degree). Bottom: meridional gradient of SST (K / lat. Degree).

This study also highlights the need for observations of the lower troposphere to properly document the low-level atmospheric circulation, too poorly simulated in the models and in order to better represent the different phases of the West African Monsoon.

2.2: Air–sea interaction in the Gulf of Guinea at the intra-seasonal scale

2.2.1: Atmospheric response to SST at quasi-biweekly time scales

de Coëtlogon, G. [1], M. Leduc-Leballeur[1], R. Meynadier[1], S. Bastin[1], M.Diakhaté[2], L. Eymard[3], H. Giordani[4], S. Janicot[3], and A. Lazar[3]

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[3] *Laboratoire d'Océanographie et Climat, Expérimentations et Approches Numériques (LOCEAN), Paris, France*

[4]*Centre National de Recherches Météorologiques, Groupe d'études de l'Atmosphère Météorologique (CNRM-GAME), Toulouse, France*

This study is a summary of the paper "Atmospheric response to sea-surface temperature in the eastern equatorial Atlantic at quasi-biweekly time scales", published by de Coëtlogon et al. in *Q J Roy Meteor Soc* in 2014. It is a dedicated study of the surface-wind response to SST and its meridional gradient in the Gulf of Guinea, by using daily observations and re-analyses from the 2000–2009 decade. The focus is on boreal spring and summer when quasi-biweekly fluctuations in the position of the northern front of the equatorial cold tongue induce quasi-biweekly equatorial SST anomalies. Results clearly suggest that intra-seasonal fluctuations of surface winds are strongly controlled by the SST or its meridional gradient in the Gulf of Guinea (Fig. 2.2 below), as far as 7°S: through a combination of both "Lindzen and Nigam" and "Sweet et al. (1981)" mechanisms, especially in the equatorial belt, and through the "Lindzen and Nigam" mechanism alone further south. Surprisingly, and in spite of an obvious influence at the seasonal scale, the northern edge of the front (around 1°N) seems to have a lesser impact on surface-wind fluctuations at intra-seasonal time scales around 3–4°N. Between the Equator and the coast, the wind fluctuations are indeed also controlled by the low atmospheric local recirculation, which progressively settles between the Equator and the coast in May-June, and in which intra-seasonal fluctuations partly fuel themselves with latent heat release at the coast, before being damped within 2–3 days. Among other results summarised, this study highlights that not only amplitudes but also the delay of the ocean and atmospheric responses to each other must be correctly represented in order for a model to reproduce a realistic intra-seasonal variability of low tropospheric winds. The "Lindzen and Nigam" and "Sweet et al. (1981)" mechanisms are intrinsically linked, but this study suggests that recognising their conceptual distinctions, with different time- and space-lagged responses, could be very useful for work on models parameterisations of boundary and surface layers. Also, the oceanic horizontal grid resolution must be high enough to simulate in a better way the strength of the atmospheric response to the sharp SST gradients.

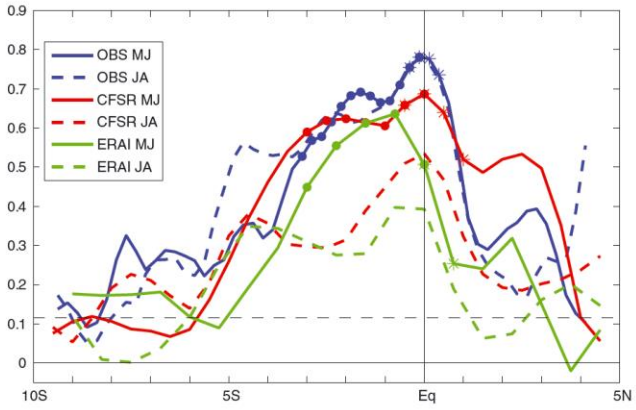

Figure 2.2: Correlation between intra-seasonal SST and wind anomalies, averaged 10◦W–0, in observations (blue), the CFSR (red) and the ERAI (green), for May-June (solid) and July-August (dashed), 2000–2009. Horizontal black dashed line gives the 90% significant correlation level with a persistence of 3 days taken into account in the time series.

2.2.2: Parameterisations of air-sea interactions in the Gulf of Guinea

Meynadier R. [1], G. de Coëtlogon[1], S. Bastin[1], L. Eymard[2] and S. Janicot[2]

[1] *Laboratoire Atmosphère, Milieux, et Observations Spatiales (LATMOS), Paris, France*

[2] *Laboratoire d'Océanographie et Climat, Expérimentations et Approches Numériques, Paris, France*

This study is summarised from the paper "Sensitivity testing of WRF parameterisations on air–sea interaction and its impact on water cycle in the Gulf of Guinea", published in *Q J Roy Meteor Soc* in 2015. In this study, modelling experiments during spring–summer 2006 with the Weather Research and Forecasting model (WRF) were carried out in order to address the uncertainties in simulating the air–sea interaction in the Gulf of Guinea and its impact on the water cycle. These experiments were compared with satellite-based observations, ship-based radio-sounding data (carried out in May-July 2006 during the EGEE-3/AMMA cruise) and state-of-the-art atmospheric model reanalyses. This allowed analysing the parameterisation and the relative importance of key parameters in the WRF cumulus, planetary boundary-layer, microphysics and radiative schemes. This study reveals that each physical parameterisation option has a strong impact on the representation of the surface wind and the water cycle in this region. One major result is that planetary boundary-layer schemes appear to have the strongest impact on the amplitude of the wind response to SST and on the water cycle. Non-local planetary boundary-layer schemes are determinant in simulating the correct surface wind pattern and water vapour distribution, needed to realistically reproduce precipitation on intra-seasonal to diurnal time scales, especially over the ocean where they lead to an improved representation of nocturnal rainfall. Also, results show that cumulus, microphysics and radiative parameterisations exert a large influence on the simulated seasonal distribution of regional convective rainfall.

2.2.3: Atmospheric response to diurnal cycle in the Gulf of Guinea

Tanguy, M. [1], L. Eymard[1], G. de Coëtlogon[2], R. Meynadier[2], G. Seze[3]

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[2] *Laboratoire d'Océanographie et Climat, Expérimentations et Approches Numériques, Paris, France*

[3] *Laboratoire de Météorologie Dynamique (LMD), Paris, France*

This study is in progress and has not been presented or published yet. A good representation of the diurnal cycle appears more and more important for the representation of intra-seasonal to interannual variability in modelling studies. The question investigated here is what frequency of ocean-atmosphere exchange is required in a coupled regional model to correctly represent the diurnal cycle and seasonal evolution in the north-eastern tropical Atlantic in boreal spring and summer (when the seasonal onset of a cold equatorial upwelling intensifies the air-sea interaction), and what vertical resolution is needed in the lower atmosphere. In addition to coupled regional simulations (WRF-NEMO) and reanalyses (ECMWF ERAI and NCEP-CFSR), extensive observational data are used, including radio-soundings and oceanic data from oceanographic campaigns in 2006 (EGEE-3/AMMA-PIRATA-FR15) and 2014 (PIRATA-FR24), airborne measurements in 2016 (EU FP7 DACCIWA campaign), in situ data from PIRATA buoys, and high-frequency satellite data (as MSG classifications in 2008, 2012 and 2014, AMSU data or TRMM precipitation). In particular, the diurnal cycle of deep convection (and its change of phase, from a midday oceanic convection to a late afternoon continental convection), as well as its dynamical conditions in the low-level atmosphere, has been regionally mapped.

2.3: Atmospheric response to SST seasonal tendency in the Eastern Equatorial Atlantic

R. Meynadier[1], L. Kounta[2], A. Lazar[3] , and G. de Coëtlogon[1]

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This study is in progress and first results were presented during the PREFACE/PIRATA/Clivar conference in August 2015, Cape-Town. The north-eastern tropical Atlantic SST becomes very warm in boreal summer, north of the seasonal equatorial cold tongue, with a maximum in the vicinity of the Inter Tropical Convergence Zone (ITCZ). This study is based on WRF simulations forced with 2000-2009 averaged atmospheric parameters and SST that are compared with simulations performed with modified-SST patterns. The aim is to understand how the strong seasonal evolutions in SST can change the atmospheric processes from the low level dynamics in the boundary layer to upper level dynamics. Special attention is given to SST-induced changes in water cycle terms, especially focusing on convective precipitation over the Atlantic but also over West Africa. Results (illustrated in Fig. 2.3 below) show in particular that the SST seasonal tendency has a clear influence on vorticity, divergence and vertical velocity throughout the whole troposphere.

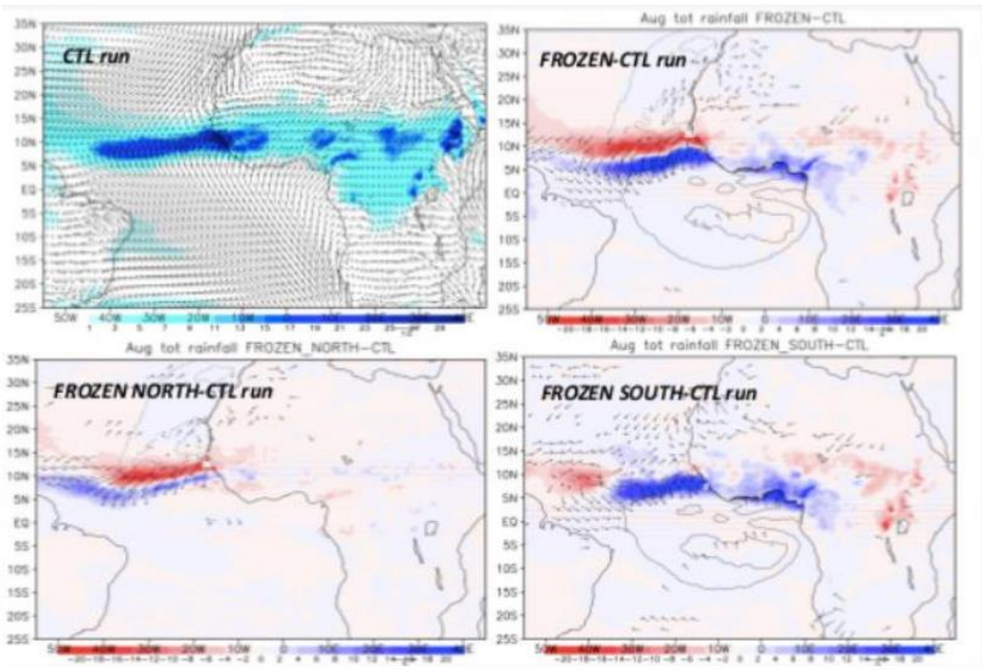

Figure 2.3: Total precipitation (shaded, in mm/d), 10-meters surface winds (m/s) and SST (contours, °K): August average in the control run and the 3 experiments testing the SST influence in the eastern Topical Atlantic

3: SST variability and related air-sea exchanges over upwelling fronts

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This study is a short summary of the paper "Intra-seasonal variability of tropical Atlantic sea-surface temperature: air–sea interaction over upwelling fronts", published by Diakhaté et al. in Q J R Meteor Soc in 2016. Air-sea interactions in the SST fronts induced by coastal and equatorial upwelling in the eastern tropical Atlantic are investigated at intra-seasonal time scales (10–90 day range) through the statistical analysis of SST and surface wind reanalysis available over the 2000-2009 decade, in five particular upwelling areas (determined by local maxima of intra-seasonal SST variance): north-west equatorial cold tongue (1°W–15°W/0.5°N–2.5°N), south-east equatorial cold tongue (3°W–7°W/0.5°S–1°N), Angola-Benguela (225 km offshore/15°S–18°S), north Senegal-Mauritania (225 km offshore/19.5°N–22°N) and south Senegal-Mauritania (17.5°W–19°W/11°N–14°N).

The study performs a detailed regional analysis of i) SST intra-seasonal variability indices, ii) surface wind / SST covariance, iii) lagged linear regression, iv) heat budget estimates in the mixed layer, and v) equatorial and coastal Kelvin waves tracking. The results indicate that in all five regions vertical oceanic mixing is a dominant term in the mixed-layer heat budget (illustration in Fig. 3 below, for the north-west equatorial cold tongue area). In the equatorial band, the horizontal advection is also important, while it appears relatively weak in the coastal fronts. Also, this study suggests a lack of surface wind signal related to the SST intra-seasonal variability in the coastal upwelling regions. However, along the equator and west of 10°W, a 20–60-day peak caused by tropical instability waves is shown to generate surface wind anomalies through the adjustment of the horizontal surface pressure gradient, in addition to the modification of near-surface atmospheric stratification. Along the equator and east of 10°W, an intense biweekly oscillation increases the ocean and atmosphere intra-seasonal variability.

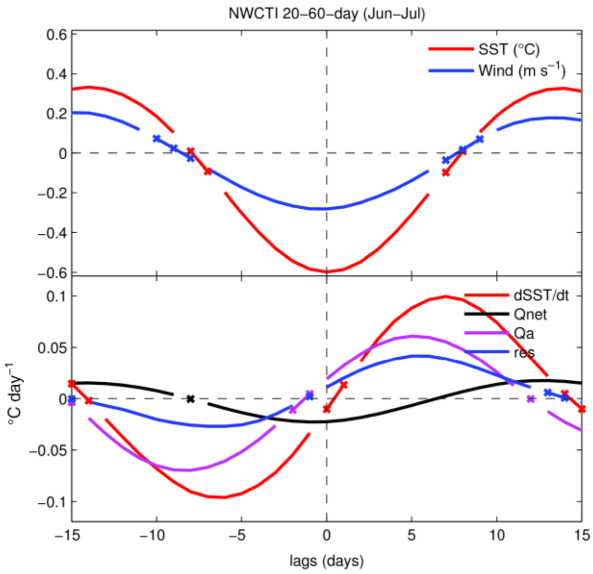

Figure 3: Lagged regressions on the (1°W–15°W/0.5°N–2.5°N) area, of:

(a) Reynolds SST (red) and QuikSCAT surface wind (blue);

(b) CFSR heat-budget terms: tendency (red), net heat flux (black), total horizontal advection (magenta), and residual (blue), averaged in the NWCTI area. Crossed parts of curves represent non-significant values.

All time-series have been band-pass filtered between 20 and 60 days, and only months from June to July are selected.

(Figure 4 in Diakhaté et al., 2016)

4: Other studies related to air-sea exchanges through mixed layer processes

4.1: Dynamic versus thermodynamic control of the Atlantic Niño

Jouanno J. [1], O. Hernandez[1], E. Sanchez-Gomez[2], F. Marin[1] and B. Deremble[3]

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[2] CECI, CERFACS – CNRS, Toulouse, France.

[3] Department of Oceanography, Florida State University, U.S.A.

This summary is related to a study still in progress (paper entitled “Mechanisms of variability of the Atlantic Niño in an ocean model forced with an interactive atmospheric boundary layer“, in preparation) that will be presented during the next PREFACE/PIRATA/CLIVAR-Atlantic conference in Paris (Nov. 28th – Dec. 2nd, 2016). In this study, the respective contributions of the dynamic and thermodynamic forcing to the variability of the Atlantic Niño are investigated using a set of 30-years simulations of the tropical Atlantic based on the ocean model NEMO. The specification of atmospheric conditions (air temperature, humidity, and wind speed), when forcing an ocean model with bulk formulae, strongly constrains the SST and thereby may impact the processes controlling the interannual variability at the ocean surface. To partly overcome this issue, the evolution of the atmospheric boundary layer temperature and humidity are computed with the marine atmospheric boundary layer model CheapAML, with the wind field is prescribed. In addition to a better representation of the air-sea exchanges, such a strategy allows to properly assess the sensitivity of the Atlantic Nino to the interannual variability of the equatorial wind work. In contrast with recent results based on state-of-the-art coupled models, suggesting that Atlantic Niño variability mainly depends on the thermodynamic component, results of this study suggest that the interannual variability of the dynamical forcing significantly contributes too.

4.2: Effect of the freshwater plumes on the SST and mixed layer

Hernandez,O. [1], J. Jouanno[1], and F. Durand[1]

[1] LEGOS, Université de Toulouse, CNES, CNRS, IRD, UPS, Toulouse, France.

These results are extracted from the PREFACE published paper entitled “Do the Amazon and Orinoco freshwater plumes really matter for hurricane-induced ocean surface cooling?” by Hernandez et al., in 2016 in J Geophys Res. Although the study area is far from the eastern tropical Atlantic, these results are of significant interest because the high freshwater discharges by Congo and other African rivers may also influence the mixed layer and SST. Based on the analysis of tropical cyclones cool wake statistics obtained from an ocean regional numerical simulation over the 1998–2012 period, forced with realistic winds, the goal was to quantify the effects of the Amazon-Orinoco river discharges in modulating the amplitude of tropical cyclone induced cooling. In both model and observations, the amplitude of tropical cyclones induced cooling in plume waters (0.3–0.4°C) is reduced significantly by around 50–60% compared to the cooling in open ocean waters out of the plume (0.6–0.7°C). A twin simulation without river runoff shows that tropical cyclone induced cooling over the plume region is almost unchanged (~0.03°C) despite strong differences in salinity stratification and the absence of barrier layers. Surprisingly, results suggest that haline stratification and barrier layers caused by the river runoff may explain only ~10% of the cooling difference between plume waters and open ocean waters and that the thermal stratification is the main factor controlling the amplitude of cooling in the plume region.

4.3: Impact of Chlorophyll concentration on SST

Hernandez O.[1], J. Jouanno[1], V. Echevin[2], O. Aumont[2]

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[2] CNRS-IRD-Sorbonne Universités, UPMC, MNHN, LOCEAN Laboratory, Paris, France

This study is a summary of a paper entitled "Impacts of chlorophyll concentrations on the tropical Atlantic Ocean" by Hernandez et al. to be submitted soon. Some preliminary results were already summarised in the PREFACE Deliverable 5.1.[4] In this study, the influence of the chlorophyll on the upper tropical Atlantic Ocean is investigated with long term (1998-2012) regional oceanic simulations with 1/4° horizontal resolution based on the NEMO3.6 model. The model solar radiation penetration scheme depends on the chlorophyll concentration. Simulations with time and spatially varying concentrations obtained from satellite ocean colour observations are compared with a simulation forced with constant chlorophyll concentration of 0.05 mg m^{-3}, representative of chlorophyll depleted waters. Results indicate that regions of the tropical Atlantic with high chlorophyll concentrations get warmer at the surface (Fig. 4.1 below), at the exception of the main upwelling regions where high chlorophyll concentrations are associated with a significant cooling of the sea surface (e.g. ~1°C in the Benguela upwelling).

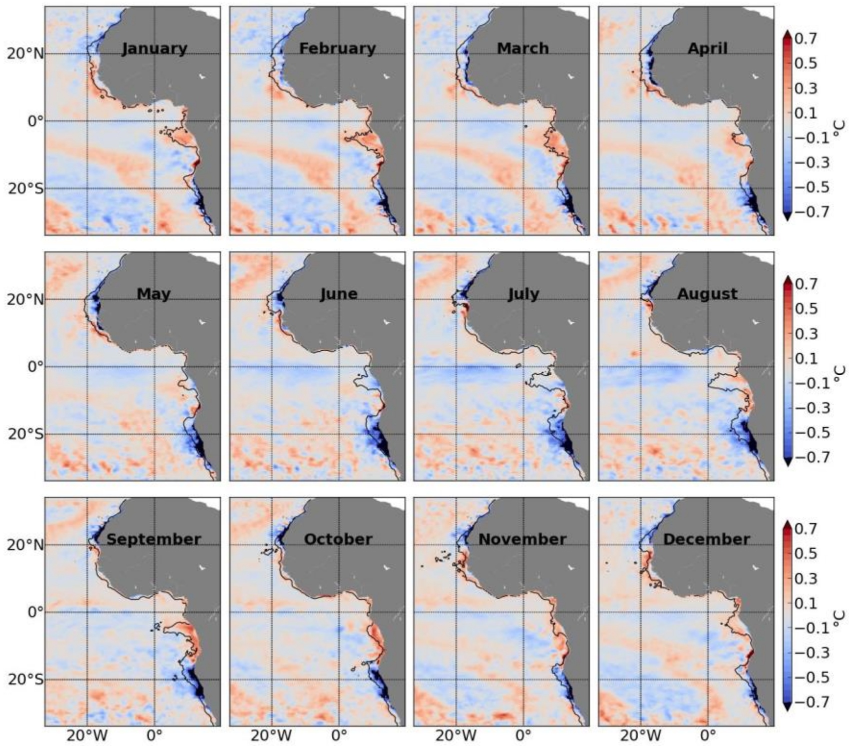

Figure 4.1: Differences in the monthly temperature in the mixed layer (in °C) between the simulation with climatological chlorophyll and the model reference simulation, averaged from 2005 to 2012. Black line indicates the 1 mg m^{-3} monthly mean chlorophyll concentration contour (Figure 5 of Hernandez et al., to be submitted).

[4] D5.1: «The role of various tested processes on seasonal to interannual variability of temperature and salinity in forced ocean models», public report, available at www.preface-project.eu

The analysis of the model heat balance shows that the biological differential heating causes negative temperature anomalies in subsurface source waters prior to their upwelling at the coast. The shallow mixed-layer in the eastern equatorial and tropical Atlantic favours the persistence of these subsurface anomalies and may explain why the Benguela is particularly sensitive to the biological differential heating. In spite of the presence of high chlorophyll concentrations in the upwelling regions, both the larger amount of shortwave radiation captured in the surface layers and the modifications of the horizontal and vertical advection at the coast are found to play a secondary role in the SST change in these specific areas.

4.4: Sensitivity of the warm SST bias in the Benguela upwelling system to wind stress forcing

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This study is a summary of the paper in preparation by Krebs et al. entitled “Assessing different hypotheses about the origin of Benguela upwelling warm bias”. Many ocean circulation and climate models exhibit a large warm SST bias in the Benguela upwelling system. The authors explore the origin of the SST bias by investigating the effects of different wind products and model resolutions. They use a global 1/2° ocean general circulation model (NEMO) with a nest around Africa with a horizontal resolution of 1/10° and higher. The model is forced by different wind products ranging from the low-resolution CORE forcing to high-resolution satellite products mostly based on QuikSCAT. The SST bias at the coast and further offshore are influenced differently. The coastal SST bias shows a strong correlation with the strength of coastal upwelling. Overall, the coastal SST bias is largely eliminated with the QuikSCAT winds and at 1/10° ocean model resolution (Fig. 4.2 below). The offshore SST bias is more complicated, since the upwelling there is influenced by the spatial and temporal resolution of the wind forcing and also by the model resolution. The offshore SST warm bias of about 1.5° C remains. Enhancing vertical resolution was not successful in reducing it either.

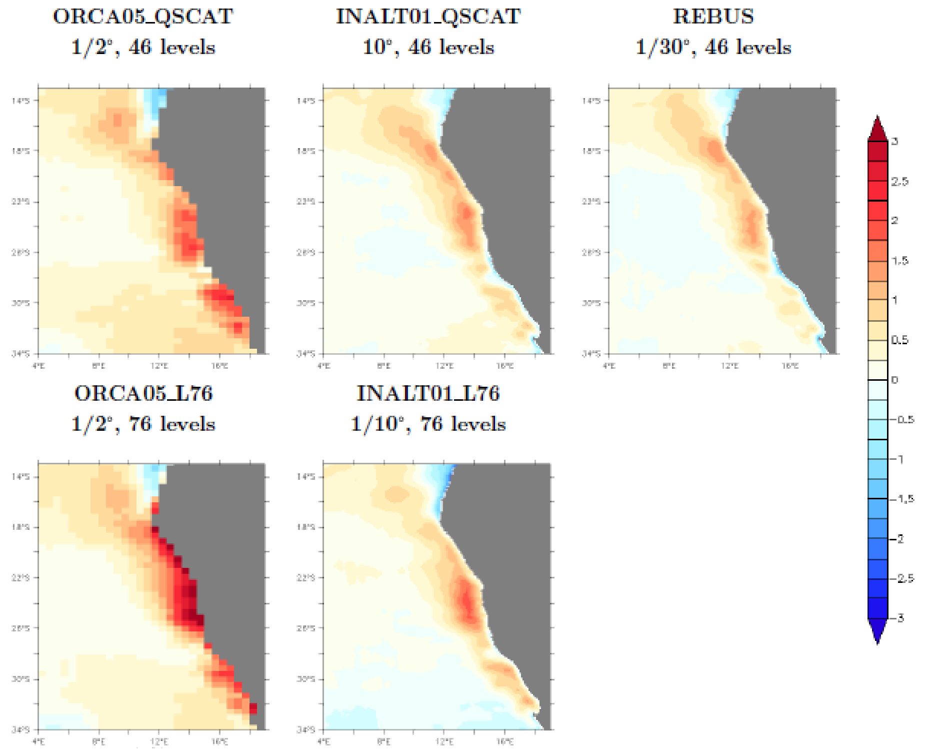

Figure 4.2: SST bias in different simulations with an ocean general circulation model (NEMO) employing different wind stress forcing and model resolutions. See titles of individual panels for further details.

References (PREFACE publications in bold)

- de Coëtlogon G, Leduc-Leballeur M, Meynadier R, Bastin S, Diakhaté M, Eymard L, Giordani H, Janicot S, Lazar A. 2014: Atmospheric response to sea-surface temperature in the eastern equatorial Atlantic at quasi-biweekly time-scales. *Q J R Meteor Soc* **140:** 1700–1714. doi: 10.1002/qj.2250
- **Diakhaté M, de Coëtlogon G, Lazar A, Wade M, Gaye AT. 2016: Intraseasonal variability of tropical Atlantic sea-surface temperature: air–sea interaction over upwelling fronts, *Q J R Meteorol Soc*** 142: **372–386. doi: 10.1002/qj.2657**
- **Hernandez O, Jouanno J, Durand F. 2016: Do the Amazon and Orinoco freshwater plumes really matter for hurricane-induced ocean surface cooling? *J Geophys Res Oceans*** 121: **2119–2141. doi: 10.1002/2015JC011021**
- **Hernandez O, Jouanno J, Echevin V, Aumont O. Impacts of chlorophyll concentrations on the Tropical Atlantic Ocean. In preparation.**
- **Jouanno J, Hernandez O, Sanchez-Gomez E, Marin F, Deremble B. Mechanisms of variability of the Atlantic Niño in an ocean model forced with an interactive atmospheric boundary layer. In preparation.**
- **Krebs M, Biastoch A, Latif M, Durgadoo J, Böning CW. Assessing different hypotheses about the origin of Benguela upwelling warm bias. In preparation.**
- Meynadier R, de Coëtlogon G, Leduc-Leballeur M, Eymard L, Janicot S. 2015: Sensitivity testing of WRF parameterisations on air–sea interaction and its impact on water cycle in the Gulf of Guinea. *Q J R Meteor Soc* **141:** 1804–1820. doi:10.1002/qj.2483
- **Meynadier R, de Coëtlogon G, Bastin S, Eymard L, Janicot S. 2016: Seasonal influence of the sea surface temperature on the low atmospheric circulation and precipitation in the eastern equatorial Atlantic. *Clim Dynam*** 47: **1127–1142. DOI 10.1007/s00382-015-2892-7**
- **Meynadier R, Kounta L, Lazar A, de Coëtlogon G. Atmospheric response to SST seasonal tendency in the Eastern Equatorial Atlantic. Poster presented at the PIRATA/PREFACE/Clivar-TAV conference, Cape-Town, South Africa, 24-28 August 2015.**
- **Pillar HR, Jochum M, Nuterman R. Characteristics of Wind-Generated Near-Inertial Waves at the Tropical Atlantic PIRATA Array. In preparation for *J Geophys Res Oceans,* 2016.**