Activities between CNRS and ESC under MOU

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This project realized in the frame a MOU between ESC and CNRS, is composed of two main themes sharing the same dynamical core of the ocean: OPA. They aim to explore (1) the impact of very shallow ocean mixed layers on the tropical climate intraseasonal variability and (2) the impact of sub-mesoscale physics on the North Atlantic balance (heat transport, nutrient cycling, CO_2 pump), both using OPA, coupled to ECHAM5 AGCM and biogeochemical model LOBSTER respectively.

Coupled model with high vertical resolution in ocean realistically reproduces the crucial role of diurnal warm layers on intraseasonal variability in the Tropical Indian Ocean and emphasizes the complex scales interactions and ocean-atmosphere coupling involved in the MJO. Second theme results highlight a strong modification in the mean circulation with resolution. Large-scale biological features are modulated by sub-mesoscale processes at higher resolutions, but enhanced turbulence introduces a complicated new production pattern.

Keywords: high resolution OGCM, mixed layer, tropical climate variability, mesoscale physics, ocean coupling with atmosphere and biogeochemistry

1. First theme: "The impact very shallow ocean mixed layers on the tropical climate intraseasonal variability"

1.1 Objective

The aim of this project is to get a better understanding and quantification of the resolved upper oceanic structures with small vertical scale that can influence the development of large scale coupled phenomena. Specific objectives of the proposed research will concern the upper ocean equatorial dynamics with a focus on the impact of diurnal cycle and the very shallow barrier layers on the tropical climate variability.

1.2 Method

To carry on this project, the use of an ocean-atmosphere coupled model is needed to explore the ocean-atmosphere interactions. The ocean component has a global 3 polar quasi-isotropic grid with a horizontal resolution of about half-degree (ORCA05) and a vertical resolution of 1 meter in the upper layers (301 levels). The Atmospheric grid is a T106 with 31 levels.

1.3 Achievements from April 2007 to March 2008

Two 30-year long coupled experiments with 31 and 301 oceanic levels have been performed. In the following, we reference them as L31 and L301. As expected, both experiments have similar mean state. Differences have to be searched out in the model variability. We first focus on the winter intraseasonal SST variability that shows spectacular differences between both simulations with an increase of 50% for L301 in area affected by the MJO in the Indian Ocean (see Fig. 1). As a result, SST intraseasonal variability of L301 is much closer to the observations (if we except the eastern part of the Indian basin). This higher SST variability is associated to the explicit representation of the SST diurnal cycle in L301. In the observations (CIRENE oceanic cam-

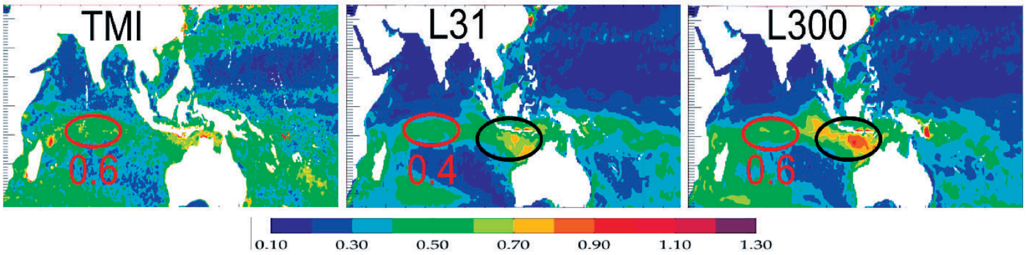


Fig. 1 Standard deviation of 20-100 day filtred SST in February. Observations (TMI) L31 and L301

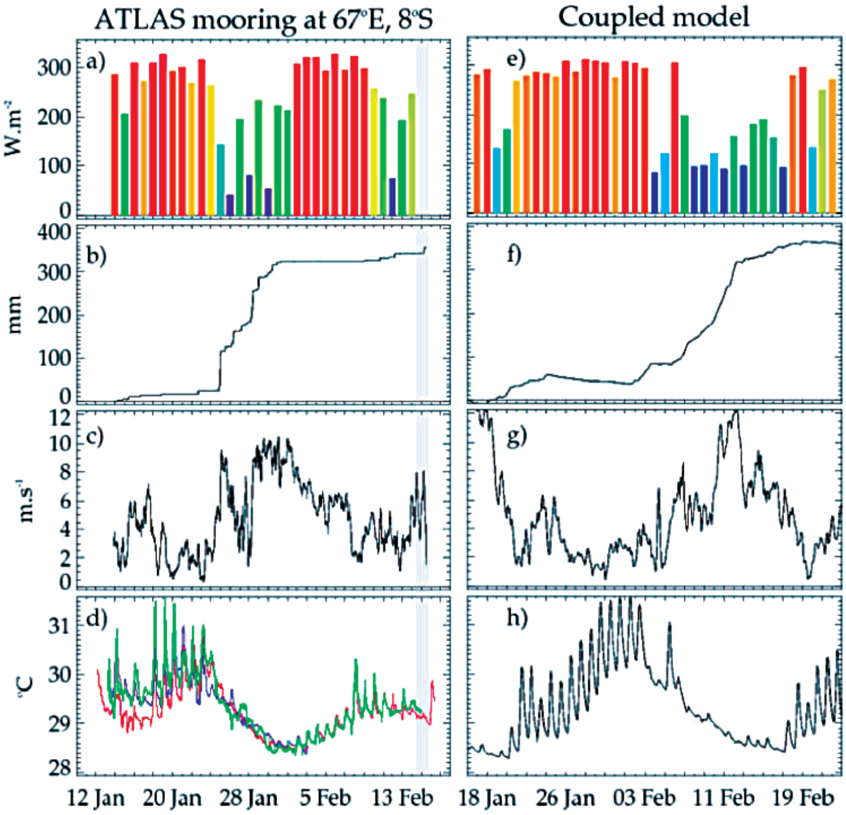


Fig. 2 From Vialard et al. [2008]. Left: ATLAS. a) Daily shortwave flux (W m-2), b) cumulated rainfall (mm), c) wind speed (ms-1), d) SST: 40 cm depth sensor from drifting buoys (in red and blue), ATLAS mooring (green). Right: L301. e) Daily shortwave flux (W m-2), f) cumulated evaporation minus precipitation (mm hour-1), g) wind speed (ms-1), h) SST (˚C). Colors in panels a and e: blue for low values and red for high ones. Note that this time section is a sample year extracted from a long coupled model simulation and that one-to-one agreement with observations cannot be expected.

paign in Jan-Feb 2007, Vialard [2008]) as well as L301, active phases of the MJO are characterized by strong winds, precipitation, weaker solar radiation and therefore SST cooling (see Fig. 2). Opposite conditions are observed during inactive phases during which SST warms up and displays a very strong diurnal cycle (around 2˚C). On average, the diurnal cycle enhances the SST warming by 0.5˚. This result, first obtained by Bernie et al. [2005] with a 1D model, is thus confirmed by our fully coupled model with a very high resolution in the oceanic mixed layer.

The formation of diurnal warm layers and the intensification of the air-sea coupling in L301 have several impacts on the propagation, frequency, amplitude and coherency of the MJO. In contrast with SST differences between L301 and L31, intraseasonal OLR variability decreases by ~30% in L301 which is in a better agreement with the observation. This decrease is explained by a more coherent (signal stronger for L301 in Fig. 3) and less noisy OLR structure in response to the intensification of the air-sea coupling in presence of the diurnal warm layers. Formation of warm layer (red circles in Fig. 3) before the arrival of the MJO followed by SST cooling (blue circle) just after MJO active event is much stronger (an even too strong) in L301 than in L31.

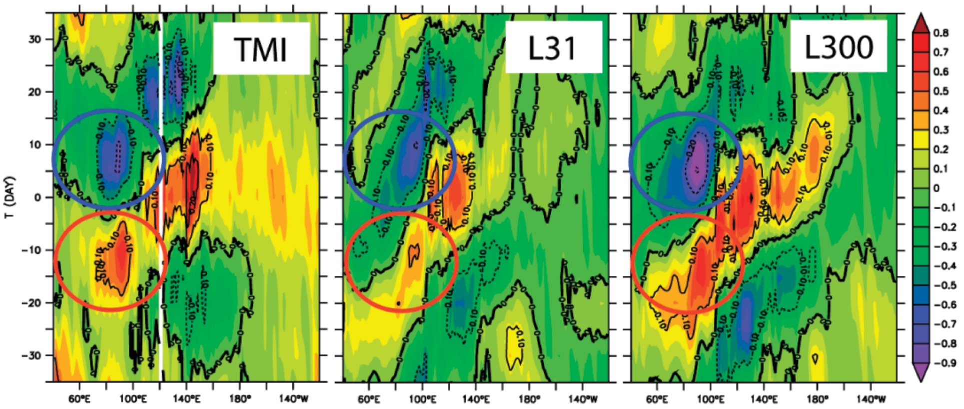


Fig. 3 Lagged correlation, l'OLR at 90˚E/ SST averaged between 10˚S et 0˚ in winter.

This illustrates the stronger oceanic response and its higher coherency with atmospheric convection (OLR). In consequence, MJO propagation speed in L301 is 30% faster and closer to observations than in L31.

1.4 Conclusion and Perspectives:

These results with a validation with in-situ observation demonstrates the quality of our coupled model and its ability to realistically reproduce the crucial role of diurnal warm layers on intraseasonal variability in the Tropical Indian Ocean. It emphasizes the complex scales interactions and ocean-atmosphere coupling involved in the MJO.

2. Second theme: "The impact of sub-mesoscale physics on the North Atlantic balance (heat transport, nutrient cycling, CO_2 pump)"

2.1 Objectives:

The scientific objective of this project is to understand and quantify the contribution of sub-mesoscale physics (eddies and filaments) on tracer distributions and on large-scale budgets (nutrient cycling, heat transport, salt transport). Specific questions are (1) Is there depletion or enrichment of nutrients in the euphotic layer on the seasonal time scale due to sub-mesoscale physics? (2) What is the contribution of the sub-mesoscale physics to the subduction of organic matter and thus nutrient cycling on longer time scales?

2.2 Method

To answer these question, we have set up a tilted wind and buoyancy forced double-gyre configuration that mimics the North Atlantic known as a crucial region of CO_2 sink. We focus on five simulations, differing in the horizontal resolution and lateral dissipation. Our most complete simulation has a resolution of 1/54˚ and couples the ocean dynamics (OPA9) with an online biogeochemical model (LOBSTER).

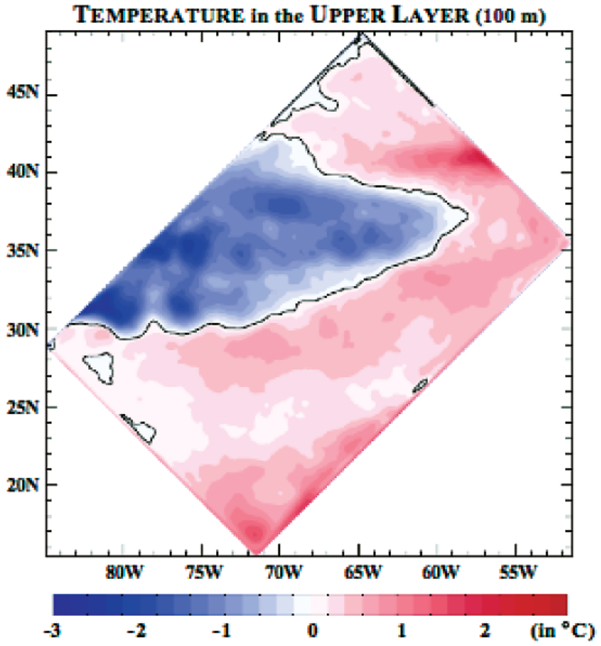
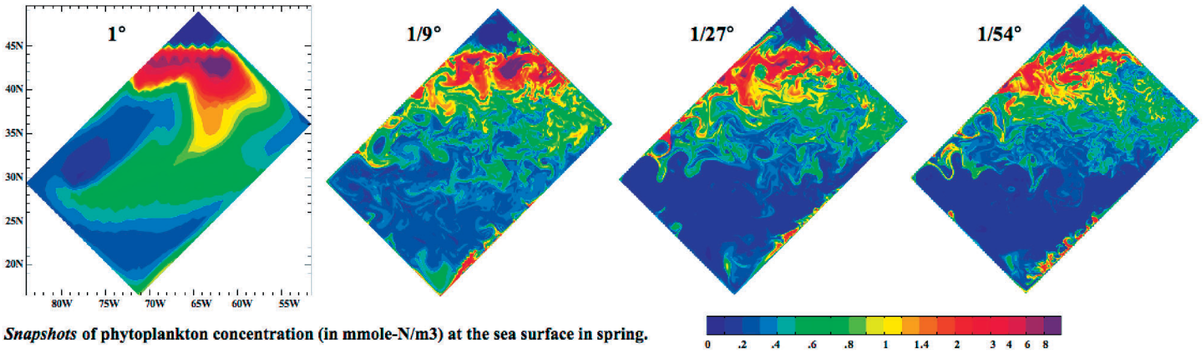


Fig. 4 Difference in annual mean 0-100m temperature between the simulations 1/27˚-1/9˚.

2.3 Achievements from April 2007 to March 2008

Our results have highlighted a strong modification in the mean circulation of the GYRE with resolution. At higher resolutions, an intense eddy field results from the instability of the western boundary current. The appearance of zonal jets at high resolution strongly reduces the size of the subtropical gyre, with large modifications of the tracer distribution. In Fig. 4, the cold tongue anomaly located between 30˚N and 40˚N is mainly due to the southward displacement of the subtropical gyre. The warm anomaly in the subtropical gyre is associated with a deepening of the main thermocline with increasing resolution. In addition, extreme patchiness of the annual mean subduction rate appears at high resolution.

Large-scale biological features are modulated by submesoscale processes at higher resolutions. Intense patches of biological activity emerge at meso- and frontal scales, asso-



***Snapshots* of phytoplankton concentration (in mmole-N/m3) at the sea surface in spring.**

Fig. 5 Sea surface Phytoplankton.

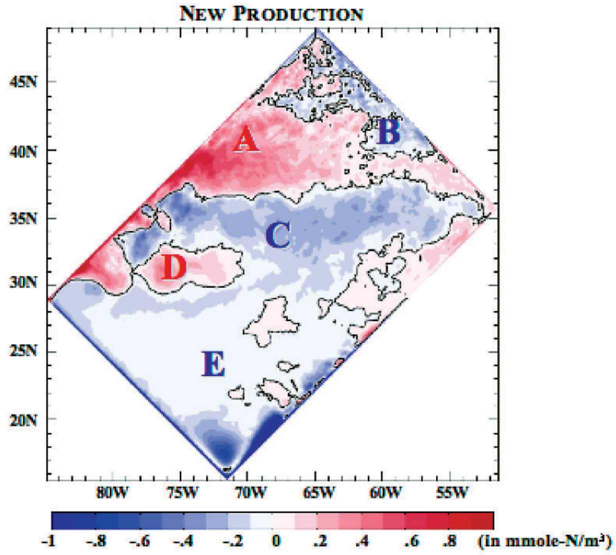


Fig. 6 Difference in annual mean New production between the simulations 1/27°- 1/9°.

ciated with energetic eddy field and vertical velocity filaments. The enhanced turbulent field results in a reduced phytoplankton concentration in the subtropical gyre and in the eastern subpolar gyre (Fig. 5). Increasing resolution does not result in an increased biological activity at the basin scale. Enhanced turbulence introduces a complicated New Production pattern with the emergence of different subregions (Fig. 6):

(A and D): shallower MLD, shallower thermocline, increased subsurface nitrate ⇒ increased New Production.

(B and E): deeper thermocline, decreased subsurface nitrate ⇒ decreased New Production.

(C): shallower MLD, increased subsurface nitrate ⇒ decreased New Production.

3. References:

Bernie, D.J., S. J. Woolnough, J. M. Slingo and E. Guilyardi Modeling 2005 : Diurnal and Intraseasonal Variability of the Ocean Mixed Layer., J. Climate, vol.18 (8), 1190–1202.

J. Vialard et al., 2008 : CIRENE : Air-seainteractions in the Seychelles-Chagos thermocline ridge region. BAMS, accepted for publication.

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本プロジェクトは、ESCとCNRSとの間の共同研究のための覚書(MOU)に基づき推進されている。2つの主要なテーマ(1)熱帯気候の季節変動における海洋混合層表層の影響、(2)北大西洋における熱輸送、栄養循環、CO_2ポンプの各バランスにおけるサブ－メソスケール物理の影響、について研究を推進する。

一つ目のテーマの結果として、非常に高解像度の海洋大循環モデル(鉛直に301層を設定)を使用した大気海洋結合モデル(大気コンポーネントの水平解像度は約100kmのT106を設定)により、熱帯のインド洋における温暖層の日変化の重要な役割の現実的な再現に成功した(図1)。さらに、MJO(Madden-Julian Oscillationと呼ばれる大規模な季節内擾乱)に関連する大気海洋結合系の様々なスケールの複雑な相互作用が存在することが強く示唆された(図2)。

二つ目のテーマにおいては、解像度の違いによる平均流れへの影響に焦点を当てて推進した。大規模なスケールの生物学的な特徴は、さらに高解像度のサブ－メソスケール過程から影響を受けており、乱流が複雑な新しい生成パターンを形成していることを強調する結果を得た。

キーワード : high resolution OGCM, mixed layer, tropical climate variability, mesoscale physics, ocean coupling with atmosphere and biogeochemistry

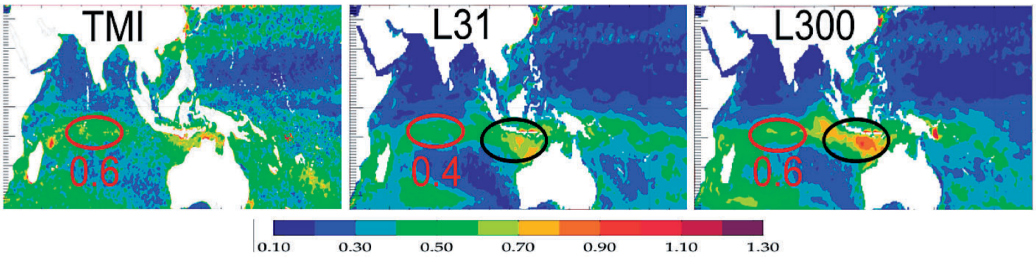


図1　冬期の季節内変動。2月の海表面温度(SST)で正規化した20～100日のSST標準偏差分布。鉛直301層を用いたシミュレーション結果のほうが、鉛直31層の結果より観測値TMIに近い変動を示している。

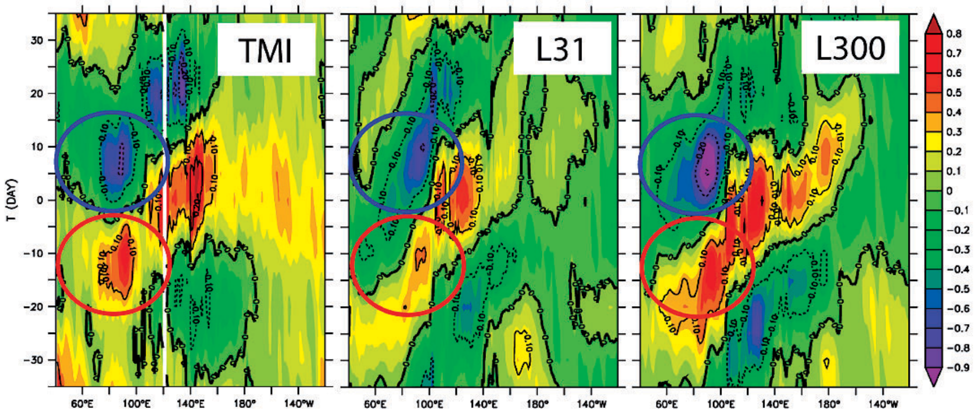
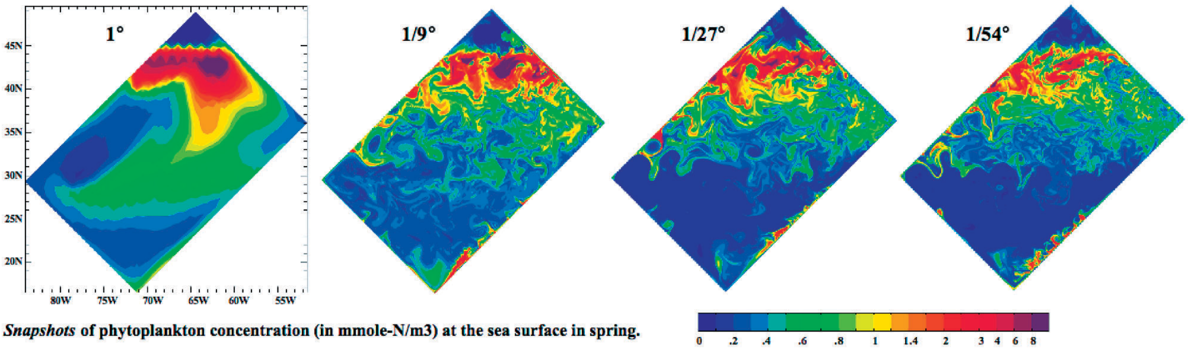


図2　(英文中のFig. 3に対応)90˚Eにおける地球から出て行く方向の長波放射と、冬期の10˚Sから0˚に囲まれた領域の平均SSTとのおくれ相関関係。鉛直301層を用いたシミュレーション結果のほうが、より観測と一致した相関を示しており、大気海洋相互作用をより少ないノイズで再現した。



***Snapshots* of phytoplankton concentration (in mmole-N/m3) at the sea surface in spring.**

図3　(英文中のFig. 4に対応)異なる解像度でシミュレーションを行ったときの海洋表面のプランクトンの分布の違い。カラーバーは、mmol-N/m^{3}単位のプランクトン濃度を表す。

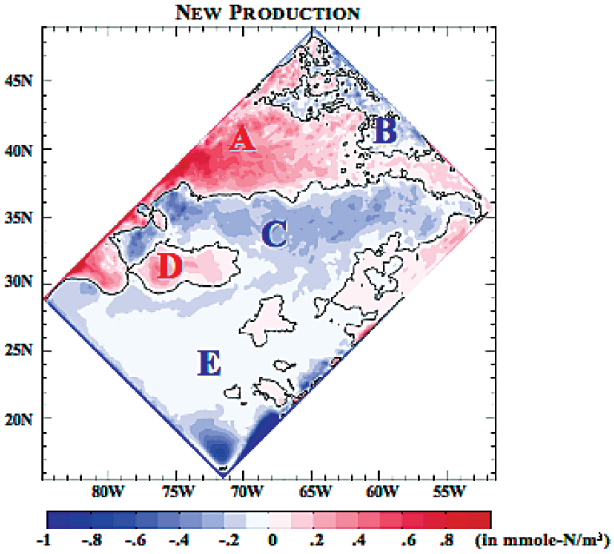


図4　(英文中のFig. 6に対応)水平解像度1/27˚のシミュレーション結果から水平解像度1/9˚の結果を差し引いた年平均分布。乱流が強い領域において新たな生成が強化されていることを示唆している。