Activities between CNRS and ESC under MOU

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This collaboration under MOU, which was signed in November 2003, is composed of two main themes: "Impact of the vertical resolution of the ocean on the tropical climate variability" and "Impact of sub-mesoscale physics on the North Atlantic balance". Both themes can not be promoted without huge experiments on the Earth Simulator. In fact, this collaboration has started since the beginning of 2005 and one scientist from CNRS has been staying to implement models and set conditions on the Earth Simulator. In the following section, each project leader explains objectives, current status and future work in this MOU collaboration.

Keywords: high resolution OGCM, mixed layer, tropical climate variability, sub-mesoscale physics, the North Atlantic

Impact of the vertical resolution of the ocean on the tropical climate variability

Name for Person in Charge:Gurvan Madec

The scientific objective 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 barrier layer on the tropical climate variability. There is a short report the results and work progress done since April 1st 2005.

Our fist task was to implement and test some new technical developments in order to improve the model performances. The original configuration of ORCA05 300 levels was suitable to use a maximum of 16 nodes.

- We strongly decreased the number of MPI communications by using a new solver and a new convergence test for the resolution of the free surface equation.
- Communications have been reorganized in order to perform less communications, each one involving a larger amount of transferred data.
- All the IO part has been rewritten in order to reduce the idle time and the size of the outputs (we use I2 instead of R4 for most of the variables)
- The order of some loops has been rewritten to take advantage of the very large number of levels and thus optimize the vectorization of some key routines.

All the performances tests have been performed. These modifications greatly improved the model performances. We are now allowed to use a maximum of 32 nodes for this configuration.

Our second task was to test several vorticity and advection schemes in order to improve the equatorial physics of OPA in its ORCA05 configuration. Gurvan Madec and Claude Talendier performed a set of experiments using different wind stress products (ERS and ERA40). Those tests have been done with the 31 levels configuration as it runs fast (1 year of simulation done in 1 hour using 8 nodes). In addition, the high vertical resolution is not necessary for this first part of the tuning. The figure 1 below shows a comparison of the zonal current along the Equator in the Pacific between observations (TAO) and model experiments. A clear improvement is visible between the first (green lines)

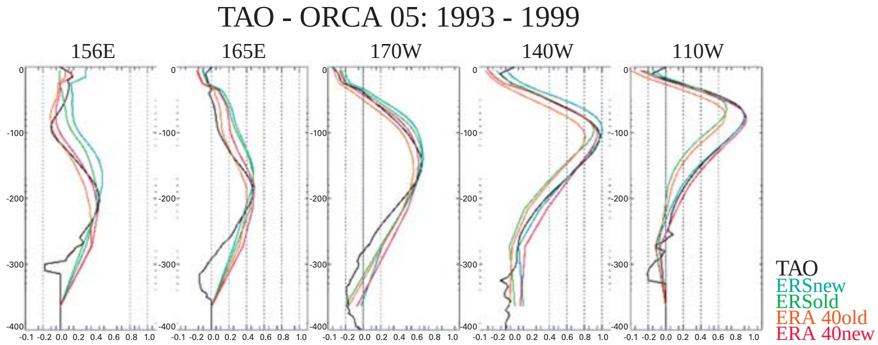

Fig. 1 Comparison of the zonal current along the Equator in the Pacific between observations (TAO) and model experiments

and the final (red lines) tests.

Model is now setting with change from the 31 levels to the 300 levels configuration. An adjustment of the model time step was needed to avoid some numerical problems associated to the very high resolution (for example in the Somalie Current). Future work will be to validate this configuration, test some different forcing (precipitation, solar radiations, bulk formulae) and introduce a parameterization of the diurnal cycle to make the first experiments on this topic on a forced configuration before moving to the coupled model.

Impact of sub-mesoscale physics on the North Atlantic balance (heat transport, nutrient cycling, CO_2 pump)

Name for Person in Charge:Marina Lévy

The scientific objective of this project is to get a better understanding and quantification of the contribution of sub-mesoscale physics (eddies and filaments) on tracer distributions and on large scale budgets (nutrient cycling, heat transport). Specific objectives are: is there depletion or enrichment of nutrients in the euphotic layer on the seasonal time scale due to sub-mesoscale physics? What is the contribution of the sub-mesoscale physics to the subduction of organic matter and thus nutrient cycling on longer time scales?

To answer these questions, we have set up an idealized double-gyre (3000 * 2000 Km) configuration that mimics the North Atlantic known as a crucial region of CO_2 sink, including the western boundary current, the subtropical and subpolar gyres and mode water formation processes. The model has a uniform horizontal resolution on the beta-plane. The basic resolution is 1 degree with 30 vertical layers. All forcings are analytical. Therefore, the resolution can be increased as many times as needed by simply dividing the nominal grid cell into smaller ones.

The most complete simulation that we are preparing has a resolution of 2 km, 100 vertical layers and couples the ocean dynamics (using the model OPA9) with an inline biogeochemical model (called LOBSTER). Here is a short report on the work done since the project has started, in April 2005.

Our fist task was to implement and test 8 different configurations (physics only). Configurations differ either in the resolution (horizontal and vertical) or in the physics. The time step and diffusion coefficients have been tuned for each configuration. We have also benefited from the developments made in the project of G. Madec regarding the optimization.

We have found that a minimum of 100 years is required to spin-up the basin from its initial state. Of the 8 configurations, 4 have run for 100 years, 3 are running, 2 are waiting. We expect to finish this first task by the end of the stay of one of project members. Preliminary results give spectacular intense fine scale structures in the vertical velocity field (Fig. 2) We expect these small-scale vertical velocities to enhance the nutrient exchanges between the euphotic layer and below, and to greatly modify the primary production budget on basin and climatic scales.

Our second task was to couple the physics with the biology. This has been done in the coarser resolution. The biological parameters and initial state have been tunned, and the results have been qualitatively validated with biogeochemical observations in the North Atlantic.

The next steps will be:

- to analyze the changes in the different contributions to upper and mid ocean transport induced by the change of resolution
- to run the coupled experiments at high resolution

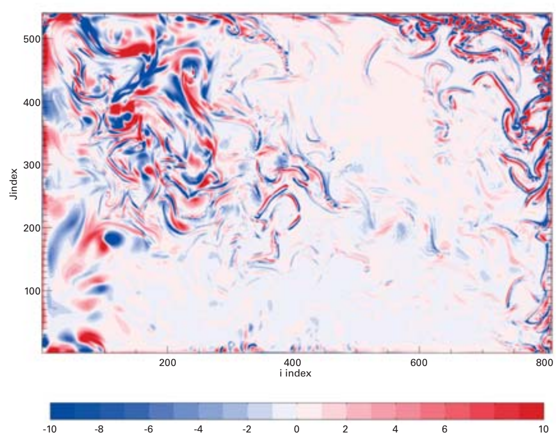

Fig. 2 Vertical velocity at 100 m depth (in m/d) in the experiment with a resolution of 4 km on the horizontal. The size of the domain shown is 2000 km x 3000 km. It is an idealized model of the two gyres in the north Atlantic.

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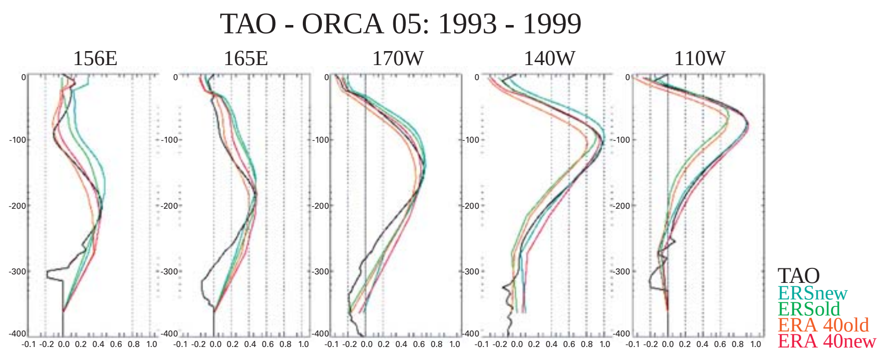
キーワード : high resolution OGCM, mixed layer, tropical climate variability, sub-mesoscale physics, the North Atlantic

本MOUの研究課題は、2つのテーマから成り立っている。ひとつは、海洋混合層の鉛直解像度を非常に高くし(300層)、混合過程の詳細かつ正確な再現が熱帯域の気候変動にどのようなインパクトを与えるかを研究する。もうひとつのテーマは、海洋のトレーサや熱輸送、栄養循環にサブスケールの渦やフィラメントがどのような影響を与えているかの機構解明である。いずれも、高解像度の海洋モデルによるシミュレーションが必要不可欠であり、地球シミュレータ以外の計算機上では数値実験が不可能である。現在、上記2つのテーマとも、目的とするモデルの地球シミュレータ上への実装をほぼ終了し、基礎的な検証実験に移行している。2005年度は、より高解像度の検証実験とともに、結合モデルでの実験にむけた準備も開始する予定である。



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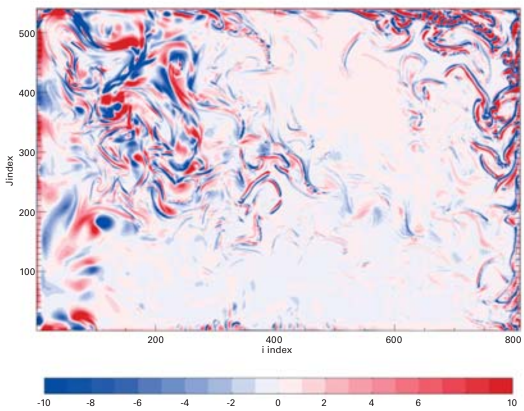

Fig. 2 Vertical velocity at 100 m depth (in m/d) in the experiment with a resolution of 4 km on the horizontal. The size of the domain shown is 2000 km x 3000 km. It is an idealized model of the two gyres in the north Atlantic