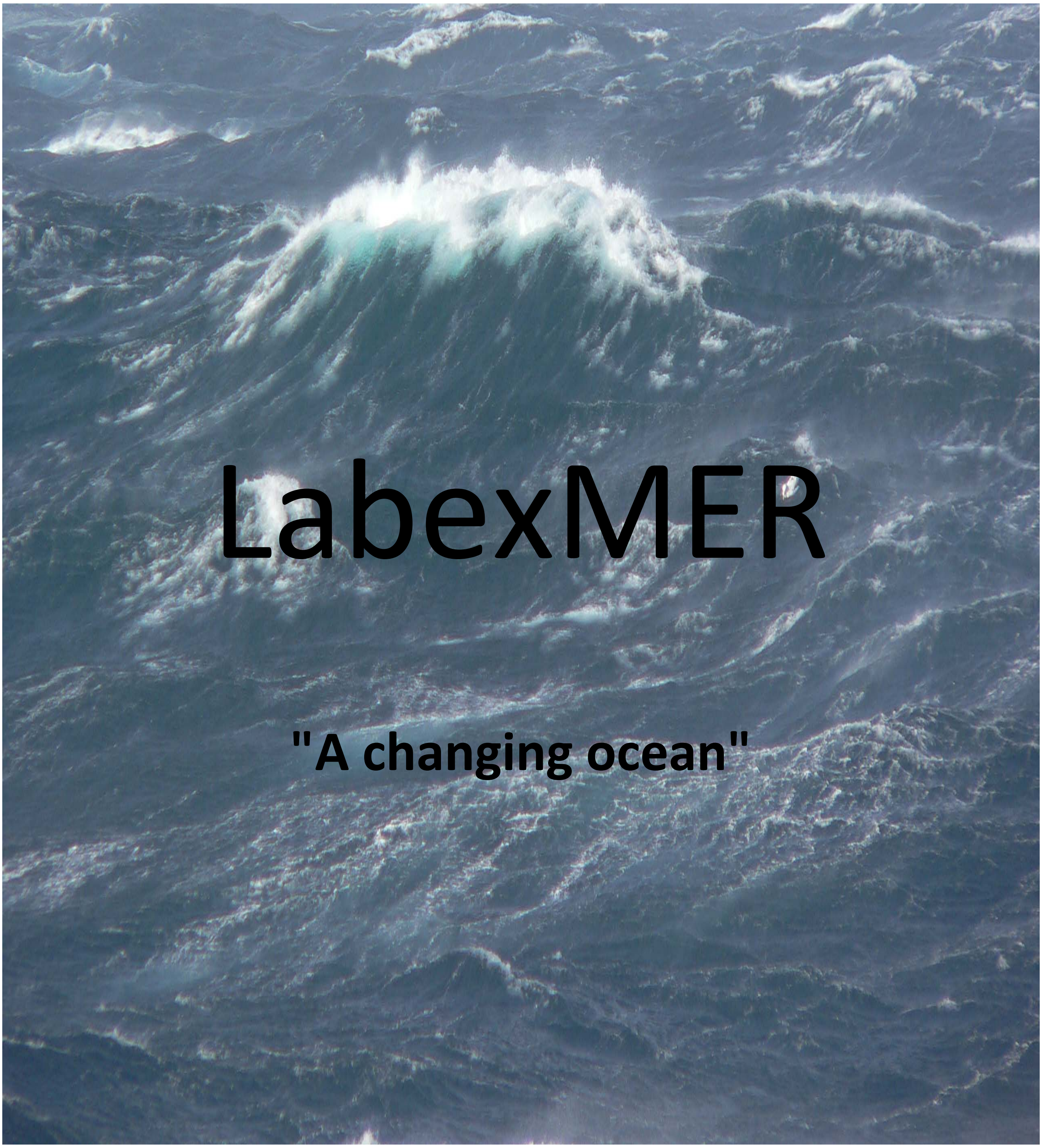

LabexMER

"A changing ocean"

LabexMER - Axis 1	**Research project 2012-2014**	**16/02/2012**

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1. AXIS 1 : THE OCEAN ENGINE AT VERY HIGH RESOLUTION

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List of participating laboratories:

- Laboratoire de Physique des Océans;
- Laboratoire d'Océanographie Spatiale;
- Laboratoire de Géosciences Marines.

1.1. SCIENTIFIC CONTEXT, SCIENTIFIC QUESTIONS, 10-YEARS VISION

a) Background, State of Art

Ocean dynamics is driven by motions involving a large range of scales from 10,000 km to a few meters and even a few centimeters. However geostrophic eddies (with diameters ranging from a few tens to 200 km), that are the building blocks of the Ocean Weather, are now known to contain almost 90% of the total kinetic energy (KE) of the flow. As such they are the major driver of ocean currents, the heat transport and of the ocean biogeochemical system. Dynamical impact of smaller scales has been for a long time mostly ignored or, for some of them (such as surface waves), studied within a small spectral range. But recent results of the last 5-10 years strongly question the interaction of these small scales with the larger ones (for example in terms of eddy dissipation) and point out the need to further decipher the scale interactions over a large spectral range.

These recent results originated from the new satellite and in-situ observations with much higher resolution than before as well as from the power increase of supercomputers. Among the major scientific advances, we can mention three breakthroughs:

- In the whole ocean interior, seismic reflection methods have been successfully used to map the internal structure of the entire water column with an outstanding resolution of 10 meters, over sections of several hundreds of kilometers length. This unveiled ubiquitous thin layers surrounding geostrophic vortices. Such layers have been reproduced through non-hydrostatic simulations of comparable resolution, revealing their coincidence with “dissipation hot spots” of kinetic energy, thus indicating a possible route to dissipation in the ocean interior.
- In the upper 500m of the ocean, submesoscales (such as 10km-wide filaments ubiquitous on high resolution satellite images) explain more than 50% the vertical velocity field, so important for the ocean biological system. More generally, numerical simulations, performed with unprecedented high resolution (500m horizontally) at basin scale, have revealed that submesoscales have strong impacts on 3D dynamics; a particular impact was shown on both the intensification and dissipation of geostrophic eddies.
- At the ocean surface, the dynamics of breaking waves is better understood to a point where their statistical properties may be predicted, and applied to upper ocean mixing, air-sea gas exchange and coastal inundation problems. While still poorly understood, models and observation indicate that this superficial mixing is partly entrained to the base of the mixed layer by Langmuir circulations induced by wave-turbulence interactions.

One common finding of these scientific advances is that all **these small scales have strong impacts on the larger ones and vice-versa.** Such results are important for the ocean KE pathways and therefore for the ocean engine. Efforts are timely to further delve into and reinforce these results before taking them into account in the new generation of climate models (through the development of new parameterisations) and for the improvement of ocean forecast models.

b) Rationale highlighting, originality of the project and strengths of the proposing team

The next step to significantly deepen and strengthen these scientific advances within the next ten years requires to use **an integrated approach.** First, to decipher the nonlinear interplay between the smallest scales with the largest ones and second to take full benefit of the strong complementarity of observational data and numerical results with high resolution (HR). Such an integrated approach implies a close cooperation between scientists from different fields (theoretical, numerical and observational) and should address a large range of scales from mesocale eddies or gyre scales, to small scales as those related to the surface wave or 3D turbulence.

Firstly, the interpretation of experimental data with high spatial resolution can now be built directly within a new and more general framework involving numerical results and theoretical concepts; this will lead to new questions. Then, we will address the challenging issue of satellite observation combination (sea surface temperature, optical and radar and sea surface topography (SWOT project)) to retrieve the upper ocean interior 3D dynamics. Also, we will interpret geoseismic oceanography data with ultra HR simulations. Finally, we will deepen our understanding and capability of predicting surface wave statistics via a combination of satellite observations (altimeter, SAR) and in situ studies of wave breaking using video techniques.
The combined and detailed analysis of the most recent HR numerical simulations with these HR experimental data and the resulting interpretation is a **major challenge for the next years.**

Scientists from Brest Laboratories are major actors in several of the scientific advances of the last 5 years and have been very active within the international community. The existence of strong numerical, theoretical and experimental expertises in these new fields on the Brest campus means that all ingredients exist **to meet this new challenge by following the integrated approach mentioned before,** which **is the originality of our project.**
Six scientists at the Laboratoire d'Océanographie Spatiale (LOS) have a well established expertise, by numerous international contributions, in the dynamics of surface waves and in the analysis of high resolution satellite measurements such as altimeter data sea surface salinity remote sensing.
Nine scientists at the Laboratoire de Physique des Océans (LPO) have recently undertaken theoretical studies on this topic and performed numerical simulations with unprecedented resolutions, most of them on the Earth Simulator in Japan (within a M.O.U. between Ifremer and Jamstec), which has led in particular to propose a new conceptual framework of the upper ocean dynamics (used in the international “SWOT” project).
Three scientists at the Geoscience (GM) laboratory are experts in seismic reflection methods and have recently started a cooperation with LPO scientists involved in high resolution nonhydrostatic numerical modelling to form the only french group involved in this new topic.
It is therefore time to integrate these scientists in a synergistic team which will address these problems with combined analyses, and which can interpret the different approaches with an enriched expertise. The framework of the Laboratory of Excellence (Labex) is the appropriate (and welcome) organisation to meet these requirements.

c) Anticipated scientific results and deliverables

Anticipated scientific results concern the identification and quantification of the different energetic pathways that connect small and large ocean scales. This should produce a new vision of the ocean engine. The deliverables should include new parameterizations of the small-scales processes to be used in the new generation of climate models as well as the improvement of ocean forecast models.

1.2. OBJECTIVES FOR THE NEXT THREE YEARS AND SPECIFIC ACTIONS

a) Scientific deadlocks: how to circumvent them?

Examples of some scientific questions that can be addressed through this integrated approach within the LabexMER are:

(1) Interactions between surface waves and the wind-forced oceanic mixed-layer and their impact on the geostrophic eddy field (using the most detailed models available such as Large Eddy Simulations (LES) models compared with in-situ and satellite data).

(2) What dynamical information on the 3-D ocean dynamics in the first 500m can be retrieved from the combined analysis of different HR satellite data using a new theoretical framework developed by french scientists at LPO.

(3) Understanding the route to dissipation in the deep ocean interior through the combined analysis of geoseismic data and HR numerical simulations,

(4) Quantifying the mechanisms by which individual mesoscale structures interact with smaller scale features and transfer energy to these scales, and at last,

(5) What are the new parameterizations to take into account these small scales in the new generation of climate models.

Meeting these objectives within the next three years requires the development of several experimental projects, combined with HR numerical simulations, which will be made much easier within the context of the LabexMER. Design of a new field (and satellite) experiment to diagnose the vertical exchanges associated with submesoscales and their relationship with the biodiversity will be undertaken in the next two years under the leadership of the LabexMER (in cooperation with several french and international (South Africa and US) laboratories. A new experiment involving geoseismic reflection methods to better monitor the small-scale processes, such as illustrated during the GO (Geoseismic Oceanography) European project should be set up whose scale will depend on the acceptation of proposals presently under review. A last project is a field (and satellite) experiment to diagnose the vertical exchanges associated with submesoscales and their relationship with the biodiversity. Experiments using stereo video cameras will improve our understanding of the interactions between wave groups, breaking-induced turbulence and surface currents.
Design of these experiments will heavily rely on coming HR simulations that will be performed on both the PRACE machines in Europe and the Earth Simulator in Japan.

b) National and international positioning of the project

The major scientific advances mentioned in section 1 result from an existing strong international collaboration involving several groups in France, the US, Japan and Russia. Within the next three years, a further significant step will be undertaken to further develop these advances and will be based on a stronger international collaboration. This is facilitated by the international context issued from development of new instruments (such as the new satellite altimeter (mission SWOT with a 1 billion of dollars budget) that will be able to capture ocean structures with a 2km-resolution) and also from the strong increase of supercomputer capacity (in particular with the European PRACE project and the Japanese RIKEN projet). Our group has already strong national and international collaboration on these topics. In particular with scientists from IPSL (Paris) through several ongoing ANR projects during the next years, which will be reinforced through future ANR projects in the next three years. Our ongoing scientific collaboration with Japanese scientists at the Earth Simulator, developed through a MOU between Ifremer and Jamstec, should be extended in 2014 for 5 more years. We have also several ongoing collaborations with US scientists through NASA projects that should be reinforced in the context of the SWOT mission and in particular within the framework of the 2012 and 2013 AirSwot experiments. And finally ongoing long-term cooperation with Russian mathematicians, fluid dynamicists and oceanographers in the context of European projects and of a European Research Group will be developed in particular in the area of the satellite data analysis.

c) New synergies between the teams and leadership

The proposed research projects should lead to new synergies between the four (five?) teams involved in our research axis, in particular between those involved in observations analysis and those involved in numerical results analysis. It is expected that within the next three years a multidisciplinary project (based on physical-biogeochemical interactions) will emerge. It would involve our axis with axis 2.

The LabexMER will be an important argument, in terms of international scientific structure, for our research axis to take the leadership, at a national and also international level, of the proposed research projects.

The three-year Labex funding devoted to the research axes, the international Post-Doc program and, the international Chairs is totally **inadequate** to successfully achieve our research projects. We intend to use the LabexMER as a leverage to get new (national and international) fundings.

For the first three-year period, the main actions of our axis will concern:

- the organisation of at least three international workshops;
- the set-up of a satellite and in-situ field experiment whose main objective is to diagnose the vertical exchanges associated with submesoscales and their impacts on the ecosystem;
- the invitation of at least one or two international scientists;
- the hiring of two or three post-docs;
- the opening of one international chair.
- the opening of one “flexible” international chair.