REQUEST FOR A SPECIAL PROJECT 2013–2015

MEMBER STATE: France

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Project Title: The freshwater representation in the Mercator Ocean global ocean reanalysis.

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP**FRESHM	
Starting year: (Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2011	
Would you accept support for 1 year only, if necessary?	YES X	NO ☐

Computer resources required for 2013-2015: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2015.)	**2013**	**2014**	**2015**
High Performance Computing Facility (units)	12000000	-	-
Data storage capacity (total archive volume) (gigabytes)	20000	-	-

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Electronic copy of the form sent on (please specify date): 27/04/2012

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[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.

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Extended abstract

It is expected that Special Projects requesting large amounts of computing resources (500,000 SBU or more) should provide a more detailed abstract/project description (3-5 pages) including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The Scientific Advisory Committee and the Technical Advisory Committee review the scientific and technical aspects of each Special Project application. The review process takes into account the resources available, the quality of the scientific and technical proposals, the use of ECMWF software and data infrastructure, and their relevance to ECMWF's objectives. - Descriptions of all accepted projects will be published on the ECMWF website.

In the last decade, real-time high-resolution ocean analysis and forecasting have become routine tasks done by several operational centers throughout the world *(Dombrowsky et al.,* 2009). Downstream applications of these near real-time operational analyses and forecasts have been demonstrated in many areas such as marine pollution monitoring *(Hackett et al.,* 2009) and marine safety *(Davidson et al.,* 2009), coastal modelling *(DeMey et al.,* 2009), ocean initialization for seasonal forecasting *(Balmaseda et al.,* 2009), support to the navies *(Jacobs and autors,* 2009), biochemistry modeling *(Brasseur et al.,* 2009) etc. Some specific applications of ocean state estimation however require long time series of the three dimensional ocean state called ocean reanalyses**.**

With its experience in the field of ocean analysis and forecasting, Mercator has developed a global ocean eddy permitting resolution (1/4°) reanalysis system *(Ferry et al.,* 2010). This work was done in the framework of the French GLobal Ocean ReanalYsis and Simulations (GLORYS) and the EU funded MyOcean projects. The objective is to produce a series of realistic (i.e. close to the existing observations and consistent with the physical ocean) eddy resolving global ocean reanalysis. A stream 2 reanalysis (called GLORYS2V1) spanning the 1992-2009 time period (the "Altimeter" era) have been produced early in 2011. The reanalysis system is similar in many aspects to the Mercator operational 1⁄4° global ocean analysis/prediction system *(Dombrowsky et al.,* 2009). Results are in very good agreement with the observation but biases have been identified. A major one is the occurrence of too fresh waters at the surface. Due to lack of in situ data at the beginning of the period, the assimilating system was not able to correct in the right way the sea surface salinity. Further analysis highlighted large biases in the precipitation fields which enter in the freshwater oceanic forcing. First attempts to correct rainfalls fields have already been tested and have shown promising results.

In this special project, we plan to use the model only component of the reanalysis system, hereafter called ORCA025. We will test an updated method of rainfalls correction, plan to implement new river discharges over the "Altimeter" era, plan also to implement the freshwater fluxes from major ice sheets melting and,finally, plan to test a new vertical turbulent scheme with a higher closure. The last year of this project will be dedicated to implement and validate all these developments in the eddy-resolving model (ORCA12, 1/12° horizontal resolution), the model component of the future Mercator Ocean reanalysis experiment.

1. System description

1.1 Model configuration

The model configuration at 1/4° is similar to the one used in the operational global ocean system operated in near real time at Mercator since November 2005 *(Drevillon et al.,* 2008a; *Drevillon et al.,* 2008b). It is a global implementation of the ocean/sea-ice NEMO numerical framework (version 3.1, *(Madec,* 2007)) and has many common features with the ORCA025 configuration developed by the European DRAKKAR collaboration *(Barnier et al.,* 2007a), the numerical details of which are given in *(Barnier et al.,* 2007b). The ocean model component is the free surface, primitive equation ocean general circulation model developed at LOCEAN *(Madec,* 2007). The sea-ice component is the LIM2_EVP sea-ice model *(Goosse and Fichefet,* 1999). The geographical domain extends from 77°S to the North Pole. The vertical discretisation uses partial steps with 50 or 75 vertical levels with an increased resolution near the surface (~1m near the surface, 11 levels above 15m depth, but 400m or 250m at bottom layers). The LIM2_EVP sea-ice model benefits from the following improvements: (i) an Elastic Viscous Plastic (EVP) dynamics of the ice and (ii) a computation at each time step of the ocean-ice stress. The model is driven at the surface by the European Centre for Medium-Range Weather Forecasts (ECMWF) atmospheric variables (see next paragraph) from their ERAinterim reanalysis products. All the experiments planned during this project will start the 1st of January 1989 with oceanic initial conditions derived from the January Levitus climatology *(Levitus et al.,* 1998) and will finish 22 years later in December 2010. The sea ice initial condition is evaluated from NSIDC sea ice fraction observations and retrieved ice thickness from previous hindcasts experiments. Coastal and rivers freshwater inputs are a monthly runoff climatology built from *(Dai and Trenberth,* 2003).

1.2 Atmospheric Forcing Strategy

Atmospheric fields are issued from the ERAinterim data set, the ECMWF reanalysis products from 1989 onwards *(Simmons et al.,* 2006). We use a 3 hours sampling to reproduce the diurnal cycle, according to *(Bernie et al.,* 2005), this temporal resolution is enough to simulate diurnal variations of the sea surface. Momentum and heat turbulent surface fluxes are computed from CORE bulk formulae *(Large and Yeager,* 2004) using the usual set of atmospheric variables : surface air temperature at 2m height, surface humidity at 2m height, mean sea level pressure and the wind at 10m height. Downward longwave and shortawe radiative fluxes and rainfalls (solid + liquid) fluxes are also used in the surface heat and freshwater budgets.

1.3 Numerical cost

In this project two models will be used: ORCA025 and ORCA12. The ORCA025 model will be used with two different vertical discretizations: 50 levels (ORCA025L50) and 75 levels (ORCA025L75). The computational cost of the ORCA025L50 configurations is 75,000 System Billings Units (SBU) per year simulated on 512 processor of C1A. The ORCA025L75 computational cost is 50% greater than ORCA025L50. After short tests performed on 2048 processors C1B we have obtained a computational cost for ORCA12 model of 2,000,000 SBU per year.

The ocean state is saved every 3 days (3 daily mean). The storage space needed for 1 year of ORCA025L50 simulation is 200Go. It represents half the ORCA025L75 configuration cost. The storage needed for the ORCA12 configuration is 3To/year.

All the experiments planned within this project with the ORCA025 configuration are supposed to start the 1st of January 1989 and ends in December 2010, i.e. 22 years of simulation. The experiment with the ORCA12 configuration is supposed to be a 6-years only simulation.

The table hereafter summarizes the costs:

	SBU/year	SBU / 22 years simulated	Storage for 1 year
ORCA025L50	75,000	1.65M	200Go
ORCA025L75	115,000	2.53M	300Go
	SBU/year	SBU / 6 years simulated	Storage for 1 year
ORCA12	2M	12M	3To

2. Improvement in the system

2.1 Twin experiment of the GLORYSV2 re-analyses

In parallel to the next Mercator Ocean reanalysis, i.e. the GLORYS2V2 simulation, a "twin" experiment (**RUN1**) with no assimilation will be performed. Compared with observations, this experiment will allow us to evaluate the benefit or the defaults from implementing the assimilation scheme in the reanalysis. This experiment will constitute the reference simulation for the next studies.

2.2 Evaluation of the impact of 75 vertical level versus 50 levels

A major difference between the new Mercator Ocean reanalysis and the real time Mercator Ocean operational system is the number of the vertical levels: 75 levels actually in the reanalysis and 50 levels in the operational system. Although both of these vertical grids have the same resolution in the upper layers, the 75 vertical levels grid has greater resolution in the thermocline layers (100-200m depth) and at the bottom layers (250m resolution instead of 450m in the 50 layers grid). A twin experiment (**RUN2**) at the RUN1 but with 50 vertical levels will be performed. Thanks to this experiment, we will be able to evaluate the impact of the vertical discretisation on the vertical processes, especially the vertical mixing in the thermocline layers.

2.3 Evaluation of the updated precipitation correction at the global scale

During last year, a method to correct the downward radiative fluxes have been developed and set up successfully This method, not detailed here, is based on an algorithm which retains the synoptic and the interannual variability of the original dataset but correct the stationary biases on a daily basis towards satellite products. This algorithm could be used even over the non-satellite era period. This method has been applied straightforward to the precipitations fluxes with the GPCPV2.1 satellite data *(Huffman et al.,* 2009). First results are shown on the Figure 1. We observe a large improvement, compared to the *(Levitus et al.,* 1998) data, of the simulated sea surface salinity (SSS) in the subtropical gyre between the reference simulation and the corrected one. Differences are still present in the European northwest coast and in the tropics (not shown). We have developed a second version of the method which is more adapted to precipitations issues and, principally, correct more efficiently the unrealistic trend present in the ERAinterim rainfalls dataset. We will test these new precipitations fields in another experiment (**RUN3**) and will evaluate especially the impact on the SSS in the tropical band.

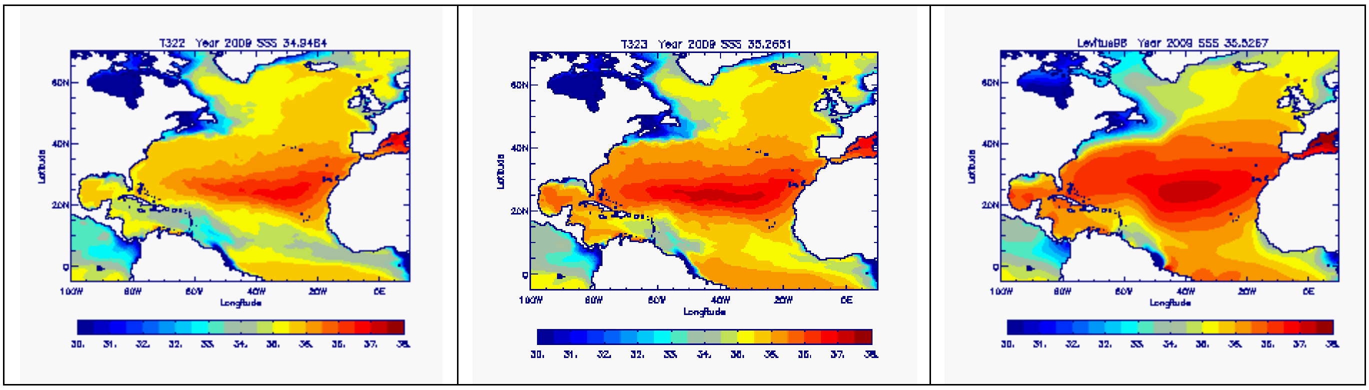

Figure 1: Mean 2009 sea surface salinity (SSS) in the Northern Atlantic basin for a simulation driven by ERAinterim precipitations (left) and by ERAinterim precipitation corrected with the first version of the algorithm (center); Levitus (1998) data is shown in the right panel..

2.4 Improvement of the river discharge input

The actual coastal and rivers runoff used in the Mercator Ocean hindcasts (reanalysis) experiments is a monthly climatological data set built from *(Dai and Trenberth,* 2003). We plan to use existing interannual runoffs data issued from the Centre National de Recherches Météorologiques, Météo France, (CNRM) model simulation (*(Alkama et al.,* 2010)) to get better representation of recent changes in the major river discharges.

We also plan to take into account a more adequate geographical distribution of the freshwater input from icebergs melting in the Southern Ocean (*(Silva et al.,* 2006)).

In the actual runoff dataset, the large and increasing melting of the Greenland and Antarctica ice sheets are not taken into account. We plan to implement these freshwater inputs thanks to estimation of the Gravity Recovey and Climate Experiment (GRACE)-based ocean mass signal (*(Llovel et al.,* 2010)).

All these developments will be deployed in new experiments (**RUN4**); we will then evaluate the impact on the freshwater budget at the global scale (sea level changes), on the local density fields and on the sea ice lifecycle.

2.5 New physical parameterization of the turbulence

A new module of the turbulence has been developed at Mercator Ocean: the Generic Length Scale module (GLS) from *(Umlauf and Burchard,* 2003). This Generic module allows a higher closure scheme than the standard TKE scheme. We want to test this new scheme and to estimate its impact on the vertical representation of the freshwater distribution in both the upper layers and, with a 20 years experiment (**RUN5**), on the water masses properties changes.

2.6 New physics parameterization of the turbulence in global high resolution model

The final goal will be to perform a simulation (6 years: 2000-2005) with the Mercator eddy-resolving configuration (ORCA12). This simulation will incorporate all the developments mentioned above giving satisfactory results (corrected precipitations, interannual runoff, GLS vertical scheme). We will then evaluate with this experiment (**RUN6**) the impact of eddies in the distribution of the freshwater input in the upper layers.

3. Description of the simulations

RUN R1: reference run without data assimilation for Mercator reanalysis project and for studies of this project

RUN R2: Evaluation on the impact of the vertical resolution between 50 versus 75 levels grid

RUN R3: Evaluation of the updated precipitations correction method.

RUN R4: Series of tests to improve the representation of the river discharges and ice sheets melting input in the ocean.

RUN R5: Impact of an higher closure scheme on vertical mixing and water masses representation

RUN R6: Test these improvements on a eddy-resolving configuration and estimation of the gain due to the horizontal resolution.

4. Planning of the project

4.1 First year: 2011

During the first year we plan to perform the RUN1, RUN2 and RUN3. The numerical costs will be 5.9 Millions SBU.

4.2 Second year: 2012

The second year of this project will be dedicated to : (1) the study of the 3 first RUN performed in 2011 ; (2) the integration of the different developments listed in the RUN4 (interannual river, Iceberg…) with different sensitivities experiments and (3) the integration of the RUN5 with the GLS scheme.

Some preliminary tests on the stability of the GLS scheme with the ORCA12 model configuration will be performed.

The sensitivities experiments before the RUN4 would be 10 years and we plan to make 3 years of ORCA12 experimental tests. Then with the RUN4 and RUN5 integrations, the numerical costs for this year would be 6 Millions SBU for the ORCA025 configuration and 6 Millions for the ORCA12 configuration.

4.3 Third year: 2013

During the last year, we will evaluate the benefits from the GLS scheme implementation and we will decide the best set among all the developments. We will then produce the six years ORCA12 simulation (RUN6) and evaluate the impact of the increased horizontal resolution. The numerical costs will be 12 MillionsSBU.

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