REQUEST FOR A SPECIAL PROJECT 2013–2015

MEMBER STATE: France

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Project Title: High resolution ocean modelling over Iberian, Biscay and Irish Seas

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SPFRIBI**	
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 ☒	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	X	X
Data storage capacity (total archive volume)	(gigabytes)	35000	X	X

An electronic copy of this form ***must be sent*** *via e-mail to:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date): April, 27th 2012

Continue overleaf

[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

Within MyOcean project (*http://www.myocean.eu.org*), Mercator Océan shares with Puertos del Estado (Spain, http://www.puertos.es) development and maintenance of a high resolution operational ocean model covering Iberian, Biscay and Irish seas (hereafter called the "IBI" system). Such a system, particularly challenging in terms of computational needs, greatly benefited from the use of ECMWF computational resources, since its early testing 5 years ago. It is now about to enter its operational production phase (in late June 2011) and will provide daily 5-day forecasts at sub-mesoscale eddy permitting horizontal resolution (1/36° ≈ 2 km). It will make use of initial and boundary conditions taken from Mercator's 1/12° North Atlantic and Mediterranean seas system (part of the global MyOcean Monitoring and Forecasting Center) and operational atmospheric analysis and forecasts from ECMWF.

Lots of developments in the NEMO ocean model have been conducted during the past years to obtain a state of the art OGCM suitable for shelf seas dynamics although it was originally designed for deep ocean modelling. Main developments dedicated to this configuration concerned the proper modelling of tidal motions, open boundary conditions, vertical mixing and advection schemes. All of these developments have been care carefully validated thanks to multiyear simulations, the main conclusion being that the resulting system has equivalent or better skills as existing models dedicated to coastal modelling over this area (*Cailleau et al, 2010, Reffray et al, 2008*).

In this special project, we propose to first investigate some topics related to the routine update of the operational system itself. Thanks to short (2 years) experiments, the key research topics planned are:

- Progressively implement some aspects of wave/ocean coupling. We would take advantage of ECMWF wave models outputs and particularly focus on the impact of coupling on vertical mixing processes. This includes the testing of recent parameterisations of non-breaking waves induced mixing (Kantha and Clayson, 2004; Huang et al, 2011).

- Investigate spectral nudging techniques to constraint part of the model spectrum thanks to the large scale model fields.

Then, we propose to perform a 24 years experiment including all the developments above. One of the objectives of this simulation is to quantify how much the model may be contaminated by numerical induced dissipation and the associated drift of deep water mass properties. This will serve as a reference to assess the need for further implementation of alternative vertical discretizations (such as ALE, "Arbitrary Lagrangian-Eulerian discretizations" currently being implemented in NEMO) or improved advection schemes. The other objective of this experiment is to study in a statistical sense the benefits of explicitly resolving sub-mesoscale processes and quantify the associated dispersion in the Lagrangian space. More generally, this kind of simulation would be pretty new at that resolution and in a realistic context with most of important high frequency processes included. It would naturally be an invaluable tool for the design and tuning of unresolved lateral turbulent mixing in coarser configurations models.

I System description

a) Numerical setup

The numerical set up of the IBI forecasting system is based on the v2.3 NEMO/OPA9 Ocean General Circulation Model (Madec 2008). The numerical core is very similar to other large scale forecasting systems in operation at Mercator Océan, so that only important changes are described hereafter. These changes arised from the need to improve the model physics on the shelf, since NEMO has been originally designed for the deep ocean. Proper simulation of tidal waves implied the replacement of the default "filtered" free surface formulation (Roullet and Madec, 2000) by a time-splitting procedure (implemented in the form proposed by

Shchepetkin and McWilliams, 2005): the barotropic part of the dynamical equations is integrated explicitly with a short time step while depth varying prognostic variables (baroclinic velocities and tracers) that evolve more slowly are solved with a larger time step. This choice is indeed required to properly simulate tidal waves without unrealistic damping (Levier et al., 2007). In addition, the default linear free surface approximation has been relaxed. In practice the vertical coordinate is rescaled from the sea level height, becoming the so-called 'z*' coordinate as described by Adcroft and Campin (2004). On a theoretical point of view, this is indeed required whenever the sea level variations are of the order of the local water depth, which is often the case on the shelf due to the occurrence of large tidal amplitudes. This also adds non linear feedbacks in dynamical equations that greatly enhance compound tidal waves and bottom stresses, thus improving the representation of tidal waves in coastal regions. Vertical mixing processes on the shelf are of primary importance, in particular because they dominate a large part of the water column. This is mainly explained by tidal motions that maintain a significant level of turbulence by enhancing bottom stresses. This induces bottom boundary layers over a large part of the water column, that eventually intersect surface boundary layers. River plumes generation and their subsequent spreading, another fundamental physical process on the shelf, are largely controlled by subtle mixing processes. Although simple and less costly one equation turbulence models (such as the default "TKE" closure used in NEMO) have often been used with success on the shelf, two-equations models appear more adapted to the various processes mentioned above. After extensive testing, the turbulence closure retained here is a k- ε version of the generic length scale (GLS) formulation (Umlauf and Burchard, 2003) with the Canuto A stability functions (Canuto et al., 2001).

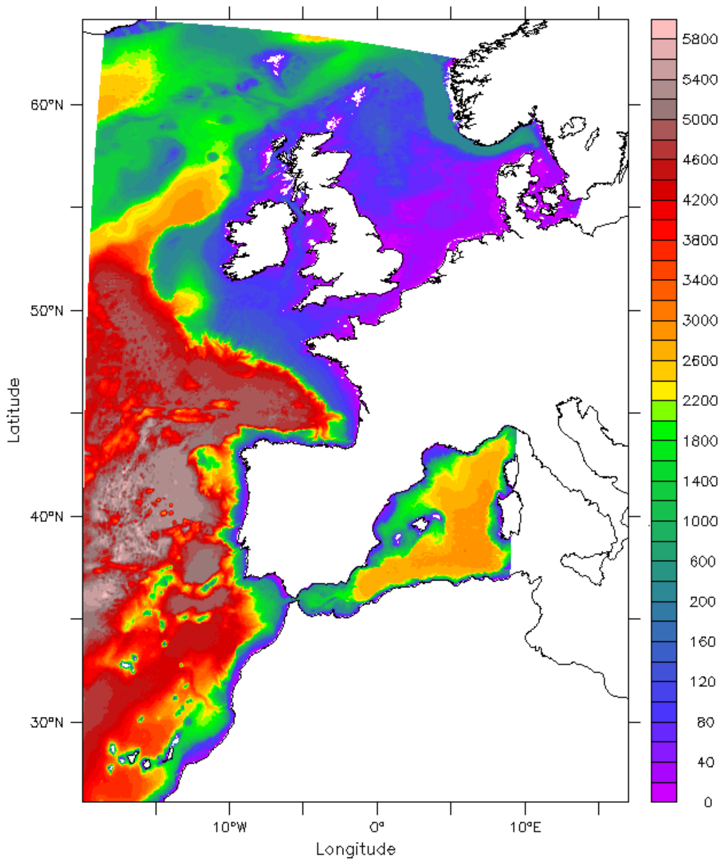

Figure 1: IBI model domain and bathymetry [m].

b) Model configuration

The IBI model configuration covers the North East Atlantic ocean from the Canary Islands to Iceland (Figure 1). It encompasses the Western Mediterranean Sea and the Skagerrak Strait that connects the Baltic Sea to the North Sea. The primitive equations are discretized on a 1/36° (~2 km) curvilinear grid extracted from the global ORCA tripolar grid used by other Mercator systems. This makes the chosen grid an exact refinement by a factor 3 of the North Atlantic system that provides initial and boundary conditions. The reference vertical grid has the same 50 geopotential levels as other Mercator systems, with grid spacing decreasing from ~1 m near the surface to more than 400 m in the abyssal plain. To improve the representation of bathymetric contours, a partial step formulation in bottom model cells is used (Barnier et al. 2006). The bathymetry is derived from the 30 arc-second resolution GEBCO08 data set (Becker et al. 2009) merged with regional bathymetries provided by IFREMER, the French Navy (SHOM, Service Hydrographique et Océanographique de la Marine) and the NOOS community (North West Shelf Operational Oceanographic System, http://www.noos.cc). The resulting bathymetry has been compared to independent ICES bathymetric data (http://www.ices.dk) to illustrate significant improvements compared to the original GEBCO08 dataset. Numerical experiments have demonstrated that this also improves the representation of tidal waves over the shelf.

c) Forcing

Meteorological fields from ECMWF every 3 hour and at 0.25°x 0.25° horizontal resolution are used to force the model. According to Bernie et al. (2005), this temporal resolution allows proper representation of diurnal cycle variations in the surface layers. Wind stresses and turbulent heat surface fluxes are computed from CORE bulk formulae (Large and Yeager, 2004) using a set of atmospheric variables that consists in air temperature, relative humidity, atmospheric pressure and wind speeds at 10 meters. Radiative heat fluxes, precipitations and atmospheric pressure are also used to force the momentum and scalar equations. Short wave radiation penetrates the surface layer according to an extension law whose extinction coefficient is dependent of the ocean color. In the model we use a monthly ocean colour climatology based on SeaWiFS data. In addition to atmospheric forcing, the model includes astronomical tidal forcing. It also includes 35 river inputs from a monthly runoff climatology built from the Global Runoff Data Center (http://grdc.bafg.de) and the French hydrographic “Banque Hydro” (http://hydro.eaufrance.fr) datasets. Initial and open boundary conditions (temperature, salinity, velocity components and sea surface height) are originally derived from the Mercator Ocean operational system over the North Atlantic at 1/12° (PSY2v3) (Hurlburt et al. 2009) solution and have been recently switched to the new PSY2v4 system. The new PSY2v4 system is operated in real time since December 2010 (MyOcean V1stream1 version). The PSY2v4 system benefits from many enhancements: multivariate data assimilation with incremental analysis updates method of bias correction, ECMWF 3-hourly forcings. In particular the incremental analysis update of the assimilation scheme allows us to restart from an equilibrate state, which was not the case with the PSY2v3 system. As both PSY2 systems do not include tidal forcing and atmospheric pressure forcing, these signals are added at the open boundaries. Tidal open boundary data for 11 constituents (M2, S2, K2, N2, K1, O1, P1, Q1, M4, Mf, Mm) are provided according the protocol described by Chanut et al. (2008). Elevations due to atmospheric pressure static effects, also known as inverse barometer effects (Wunsch and Stammer, 1997) are computed from the ECMWF pressure fields.

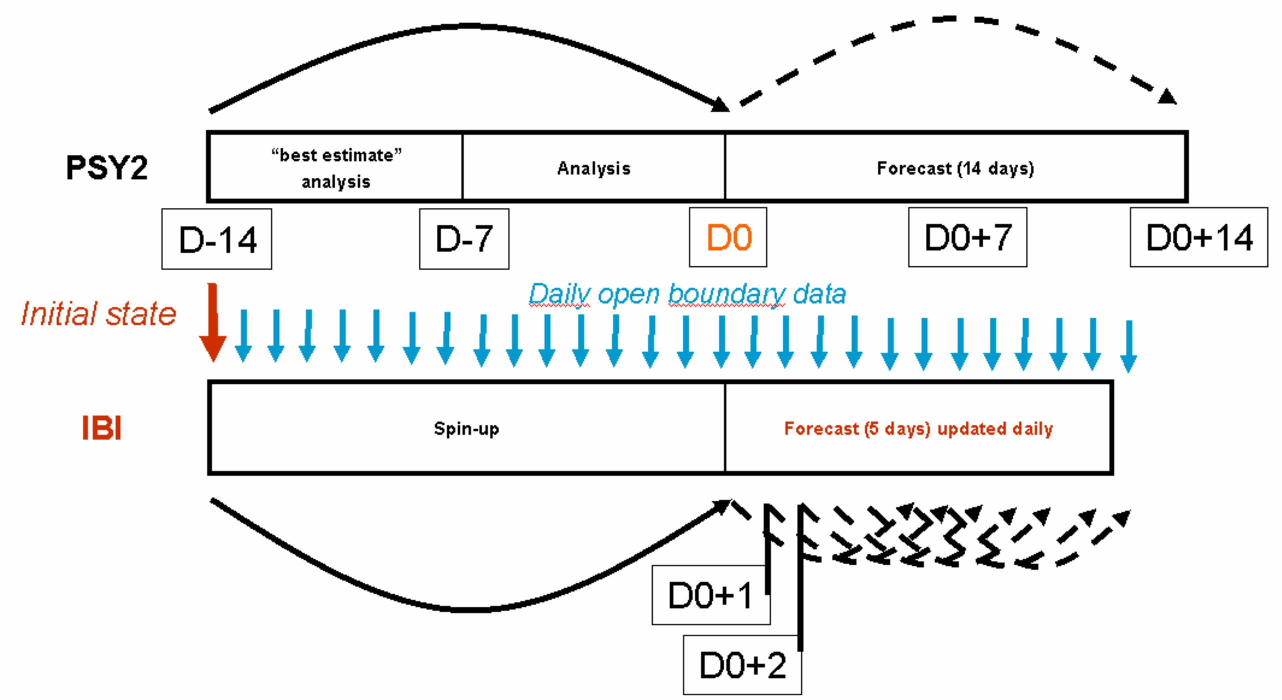

Figure 2: Operational protocol scheme of IBI system

II Numerical cost

The computational cost of the IBI configuration is 500,000 System Billings Units (SBU) per year simulated on 543 processors of C1A.

The ocean state is saved every day for 3d arrays and every hour for 2d variables such as sea level, surface velocities, barotropic velocities and surface temperature. The storage space needed for 1 year of IBI simulation is 1.4 To.

III Improvement in the system

a) Calibration of V2 MyOcean system

Slight modifications of the IBI MyOcean V1 system are scheduled in 2011 to be included in the next MyOcean IBI release. This mainly concerns the optimization of bathymetry and some numerical parameters in key straits. The use of realistic daily river flowrates taken from observations or hydrological models (instead of climatological monthly river flowrates) will also be included as well as updates of time interpolation procedures for atmospheric fields.

- ⇨ A calibration run needs to be performed to assess that no regression from v1 systems arise from these changes.

b) Improvement of operational protocol

The downscalling methodology used in the operational context is depicted in Figure 2 and is inherited from the strategy developed for the ESEOAT system (Sotillo et al. 2007). Every week, the regional system is initialized in the past from analysed outputs (3d temperature, salinity velocities and sea-level) taken from the PSY2 system and bilinearly interpolated on the refined grid. The model is then integrated until D0 to allow the spin up of small scales and the convergence of physical processes that are not resolved by the parent system. The analysed output at D0 is then used to provide one week forecasts until the next analysis stage.

- ⇨ We propose to improve the operational scheme by including ad-hoc spectral nudging to the parent system fields during the spin-up phase. The objective is to improve the consistency of meso-scale structures between the two systems and consequently limit the discontinuity induced by the sequential restarting of IBI. This is also a way to take advantage of the data assimilation step performed in the global system between D0-14 and D0.

c) Wave-ocean coupling

We propose to progressively implement some aspect of wave-ocean coupling in the system. This work has already begun with respect to the use of wave induced surface stresses in addition to wind stress only.

- ⇨ Taking advantage of ECMWF wave models outputs we plan to extend the coupling to the inclusion of Stokes-Coriolis force, and to terms related to vertical mixing processes (wave to ocean turbulent kinetic flux, surface roughness from wind sea height, Stokes drift mixing).

IV Description of the simulations

RUN R1: 2 year run used as calibration test for MyOcean v2 (Task III.a)

RUN R2: Improvement of operational protocol. Parameters concerning the spectral nudging cutoff frequency, and nudging tapering on the shelf need to be explored. Performing the required tests according to the protocol described in III.b roughly requires an equivalent 2 years continuous simulation.

RUN R3: Step by step implementation of wave/ocean coupling terms described in III.c. Ultimately two 2 year experiments to be compared to R1 to be produced.

RUN R4: 10 years run forced by ERAinterim data set, preparation of the long inter-annual simulation R5.

RUN R5: 24 years run forced by ERAinterim data set used for statistical purposes and drift monitoring.

V Planning of the project

a) First year: 2011

Sensitivity experiments: 4 M SBUs
Runs R1, R2: 2 M SBUs

b) Second year: 2012

Sensitivity experiments: 5 M SBUs
Runs R3: 2 M SBUs
Run R4: 5 M SBUs

c) Third year: 2013

Run R5: 12 M SBUs

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