BMGTOOLS: A COMMUNITY TOOL TO HANDLE MODEL GRID AND BATHYMETRY

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Abstract

A software called BathyMeshGridTools is proposed to facilitate the construction of gridded bathymetry data for hydrodynamic ocean models from global to coastal scales. These tools consist of a graphical interface written in Java and a computational core written in FORTRAN, which are freely distributed under LGPL and GPL licenses (http://www.ifremer.fr/bmgtools). The process of gridded bathymetry creation relies on three successive tasks: (1) creation of structured grid using graphic user interface for positioning, resizing and creating a hierarchy of nested model grids on a map; (2) data interpolation using a grid-to-grid interpolation algorithm for interpolation of Digital Terrain Model and kriging algorithm for bathymetric sounding data interpolation; (3) visual inspection and manual editing of the interpolated bathymetry field. These three steps can be used in the same process of construction of bathymetry gridded data and can also be used independently (*e.g.* one can use only the visualization tool for checking and modifying manually a bathymetry field previously created with an other tool).

Introduction

Before launching numerical simulations, it is necessary to perform various preprocessing tasks to prepare the input fields. The BMGTools (BathyMeshGridTools) are a set of pre-processing tools that helps to create, check and modify bathymetric grids in an easy, fast and interactive way. CreateBMG is a part of the BMGTools package. Its purpose is to help create a hierarchy of nested grids on a map, resize them and interpolate bathymetry data on the created model grids, either from bathymetric sounding measurements or from digital terrain model. CheckBMG is also part of the BMGtools package. Its purpose is to help to visualize bathymetric grids created with CreateBMG - or with other applications - and to check the relevance of the interpolation. If necessary, the users can modify the grid manually in the aim to correct the interpolation algorithm errors.

BathyMeshGridTools: a tool to handle model grid and bathymetry

Both graphical user interfaces that handle the grid creation and the visualization/correction of the interpolated bathymetry on the grid are entirely written in JAVA which gives them a good portability and which ensures an easy installation. CheckBMG and CreateBMG runs under Unix/Linux 32/64 bits, Mac OSX and Windows 32/64 bits operating systems using the suitable JAVA library which is integrated in the distribution. The computational part on data interpolation is written in Fortran90 so the user can read, understand and modify the code as they wish. In order to facilitate the compiling task on each platform, a user can handle the cross-platform, open-source build system CMake[1] to generate the appropriate Makefile. Bmgtools is composed of three distinct features. These three features are: the creation of grids, the interpolation of data grids and the verification of interpolated bathymetric grids. These three features can be used independently.

- Grid creation (CreateBMG)

Within BMGTools software, CreateBMG aims at faciliting the creation of model grids with the help of a Graphical User Interface (GUI) and by using some geographic information system functionalities. To adjust the geographical domain, several geomorphic elements like coast line, isobath or physical field can be displayed. Modification of mesh grid resolution or creation of a hierarchy of embedded grids, as required for the AGRIF[2] refinement method for instance, are interactively and rapidly achieved through the GUI (Figure1). The createBMG tool can handle various C-Arakawa type model grid such as rectangular grid used by several modeling codes and especially by the MARS3D[3] code used in the PREVIMER operational system or more complex grid such as the ORCA grid. Thus, this tool allows to create sub-grid by calling a fortran code use in building the NEMO[4] grid (*i.e.*ORCA grid). The horizontal mesh grid files are written in netcdf format. The netCDF format uses the COMODO[5] convention (http://pycomodo.forge.imag.fr) to be compliant with most of ocean models (MARS, NEMO, SYMPHONIE[6], ROMS[7], HYCOM[8]).

[1] CMake : http://www.cmake.org
[2] AGRIF : Adaptive grid refinement in Fortran - http://www-ljk.imag.fr/MOISE/AGRIF
[3] MARS3D: coastal ocean numerical model developed in Ifremer - http://wwz.ifremer.fr/mars3d
[4] NEMO : Nucleus for European Modelling of the Ocean - http://www.nemo-ocean.eu
[5] COMODO : French Numerical Ocean Modelling Community - http://pycomodo.forge.imag.fr
[6] SYMPHONIE : http://sirocco.omp.obs-mip.fr/outils/Symphonie/Accueil/SymphoAccueil.htm
[7] ROMS : Regional Oceanic Modeling System - http://www.romsagrif.org/index.php
[8] HYCOM : HYbrid Coordinate Ocean Model - http://hycom.org
[9] SCRIP : Spherical Coordinate Remapping and Interpolation Package - http://climate.lanl.gov/Software/SCRIP

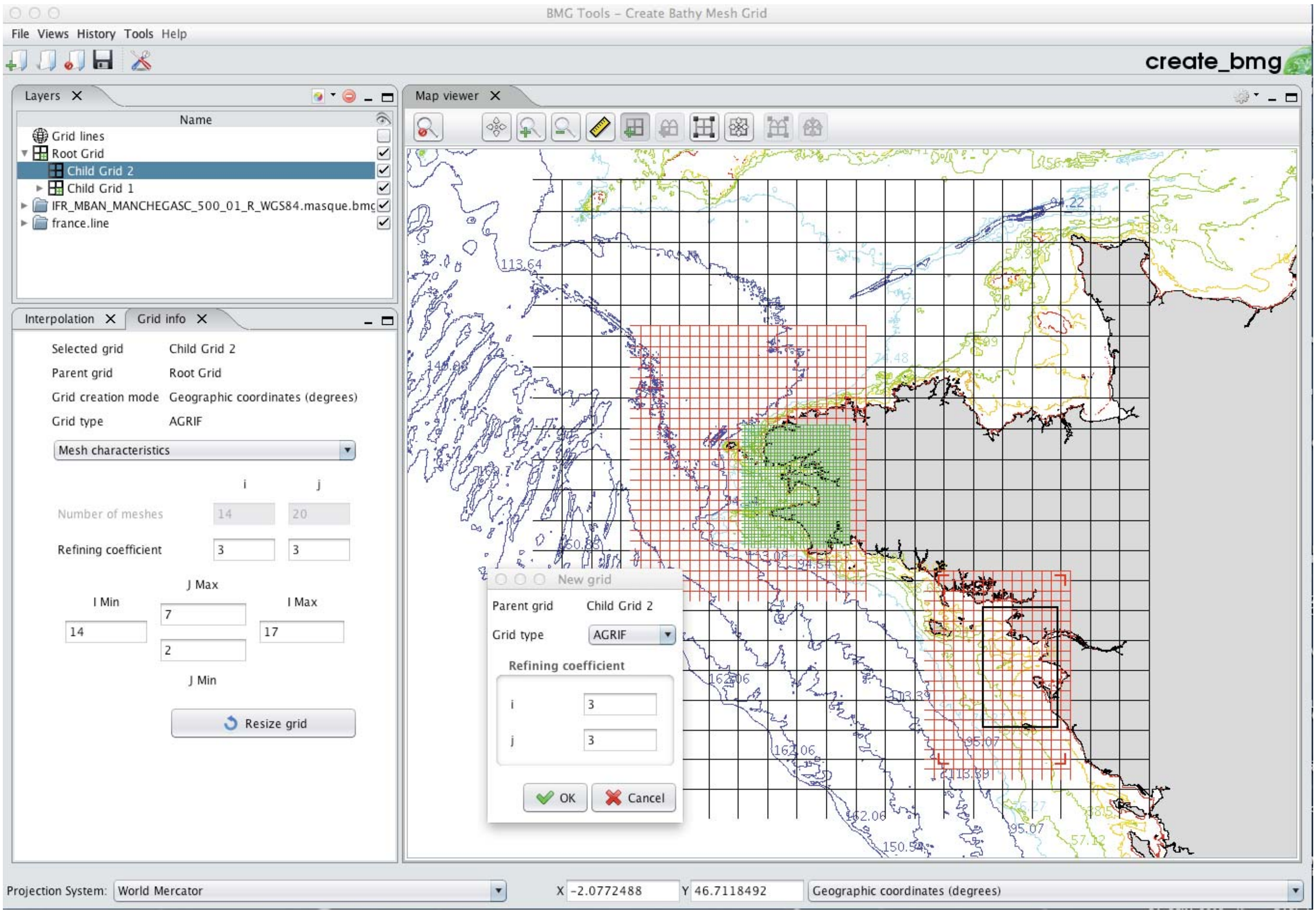

Figure 1: Screenshot of the CreateBMG Graphical User Interface used to create a hierarchy of AGRIF embedded grids

• Data interpolation (CreateBMG)

CreateBMG can also be used to generate a gridded bathymetry, either from sounding data coming from oceanographic survey or from digital terrain models. The use of sounding data is often preferred for high resolution coastal hydrodynamic models (grid-cell size less than 1 km) whose realism strongly depends on the realism of the gridded bathymetry. In that case, spatial distribution and density of sounding points are first compared to the grid resolution and to its geographical extension (Figure 2). Sounding data are then interpolated following the data preprocessing methodology and the kriging algorithm described in Bailly du Bois (2011). For a larger geographical extension and coarser grid resolution, the interpolation of one or several digital terrain model is usually made. In this case, the structured digital terrain models are interpolated by using the SCRIP[9] algorithm. Both interpolation codes are written in Fortran offering the possibilty to users to read, understand and modify (even improve) the codes. The GUI makes a system call to the Fortran executable. It implies that the Fortran executable can be used without the CreateBMG GUI on any suitable machine if more memory is needed to interpolate a large amount of data.

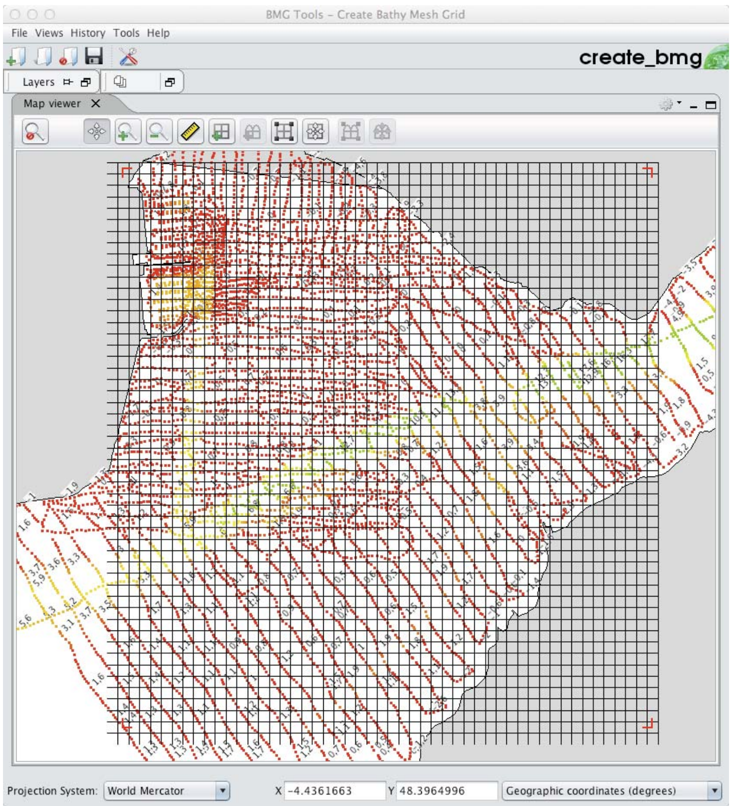

Figure 2: Visualization of a set of soundings and grid before interpolation in the CreateBMG Graphical User Interface

• Visual inspection, manual editing and some other useful tools (CheckBMG)

The second graphical user interface called CheckBMG is certainly the most popular and the most used within the ocean modeler community. CheckBMG provides many functionalities that helps in working on the bathymetry grid. Here are somes examples :

- The fastidious task of visualization and checking the interpolated bathymetry grid is now greatly facilitated by using this tool. The JAVA developments that have been made allow fluidly and interactive visualization of large grids (benchmarked up to 1000x1000 grid points). In addition, the display performance remains satisfactory even when different layers of geographic information, like coastline or physical fields (Figure 3), are added. The user may realize many intuitive actions with the computer mouse like zoom, unzoom, display or not of geographic information layers. By playing with the range of the color bar, the user can explore the interpolated bathymetry values more finely. In case of working on larger bathymetry grids or with a insufficiently powerful computer, the user can also only work on a sub-region in order to decrease the memory and cpu needs.

- Sometimes because of limitation in the interpolation algorithms or because of the poor data quality, the user has to modify interpolated values “by hand”. The user could also want to modify the bathymetry for specific purpose. For example, fill an estuary or a bay that is not relevant for a given application, dig an artificial channel with the objective to test the influence of a bathymetric modification on the model solution; modify the bottom depth values in some area in order to improve the physical solution of the model. Owing to CheckBMG, this bathymetric values modification process is both quick and easy : the user selects a point or a set of points with the mouse and enters the new value. This change is then updated automatically and instantaneously in the NetCDF file.

- Based on these previous features other tools are available to the user for perform other manipulation on the grid. Thus, one can create and modify the runoff locations on the grid. One can also selects specific points on the grid, save it in a text file for use in the model or in another application.

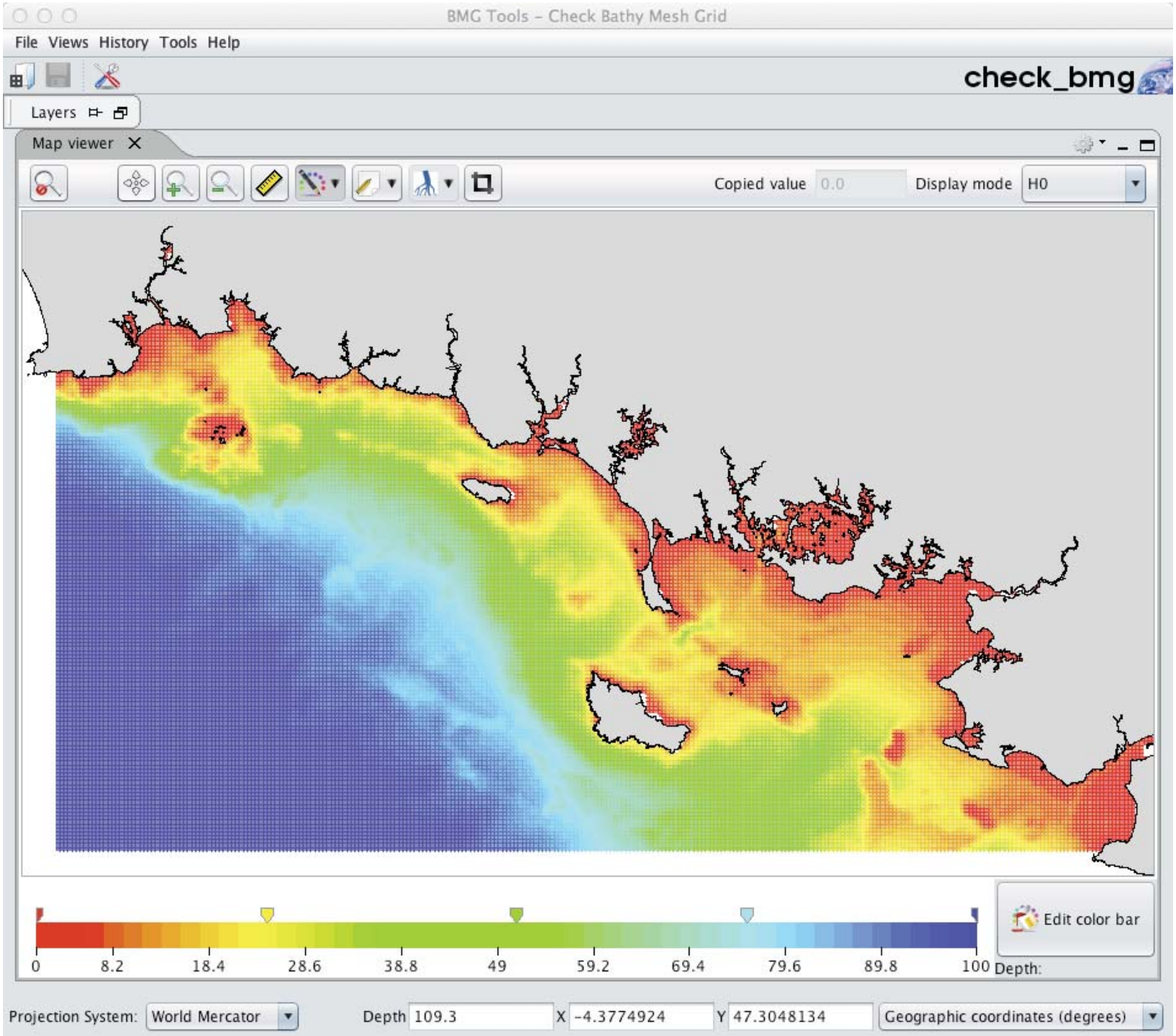

Figure 3: Visualization of interpolated bathymetry for checking and manual modifying process

BathyMeshGridTools: a pre-processing community tool. Two examples of application in operational systems

• Operational Coastal Oceanography system : PREVIMER[10]

Many model configurations are required to cover the metropolitan France coastal zone and overseas regions. Each of those model configurations have different resolution (*i.e.* 4 km to 50 meters) and also different spatial extension (*e.g.* Bay of Biscay to the Rade de Brest (Figure 4)). To build all those model configurations we need robust and reliable tools to generate all the input fields required for the simulation. In the case of PREVIMER, the whole BathyMeshGridTools package is used. The grid are built with createBMG and both interpolation algorithms (SCRIP grid-to-grid interpolation for digital terrain model and kriging algorithm for sounding data) are used. CheckBMG is used in the last step specially to check the proper definition of shallow water bathymetry near the coast.

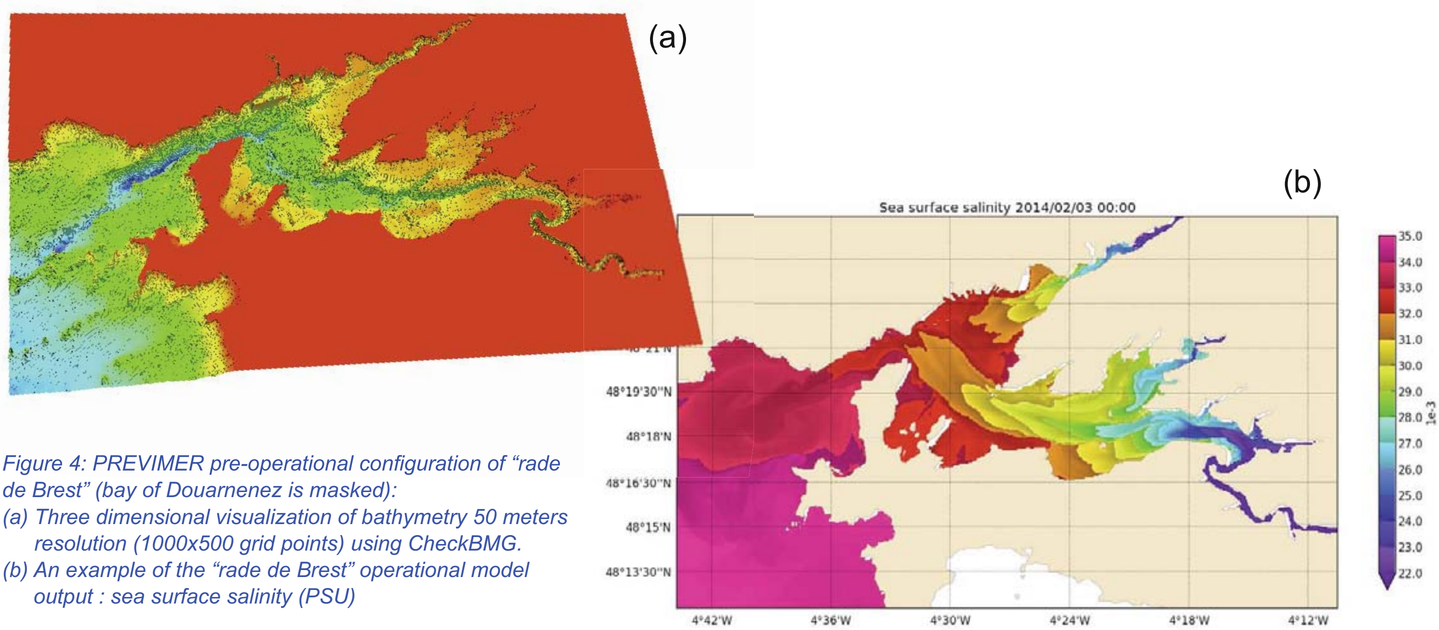

Figure 4: PREVIMER pre-operational configuration of "rade de Brest" (bay of Douarnenez is masked):
(a) Three dimensional visualization of bathymetry 50 meters resolution (1000x500 grid points) using CheckBMG.
(b) An example of the "rade de Brest" operational model output : sea surface salinity (PSU)

• MERCATOR OCEAN[11]

The CheckBMG tool is integrated to the Mercator Ocean System and Interface RElocatable Nesting tools (SIREN). SIREN allows users to create a new configuration embedded in a larger one. To do so, it creates merged bathymetry, initial state and boundary conditions. In a first step, SIREN extracts fine grid bathymetry over the domain of interest and merge it at boundaries with coarse grid bathymetry. In this context, CheckBMG is used to check and to adjust locally the bathymetry created for the new regional configuration.
For example, Mercator Ocean develops, in collaboration with CLS, an operational system over the Indonesian archipelago named INDESO. SIREN was used to create it. This configuration is based on the ORCA12 grid. First, the data collected during the INDOMIX Campaign have been included in the ORCA12 bathymetry (Figure 5). Moreover, to improve the transport in LUZON (LST: Luzon Strait Transport) several straits have been corrected, *e.g.* Surigao strait, Mindoro strait. CheckBMG was also used to correct the Mindanao strait and other Island position (like Sibutu island). All these changes have been made from Googleearth, ETOPO 1 and the GSHHG - A Global Self-consistent, Hierarchical, High-resolution Geography coast line.

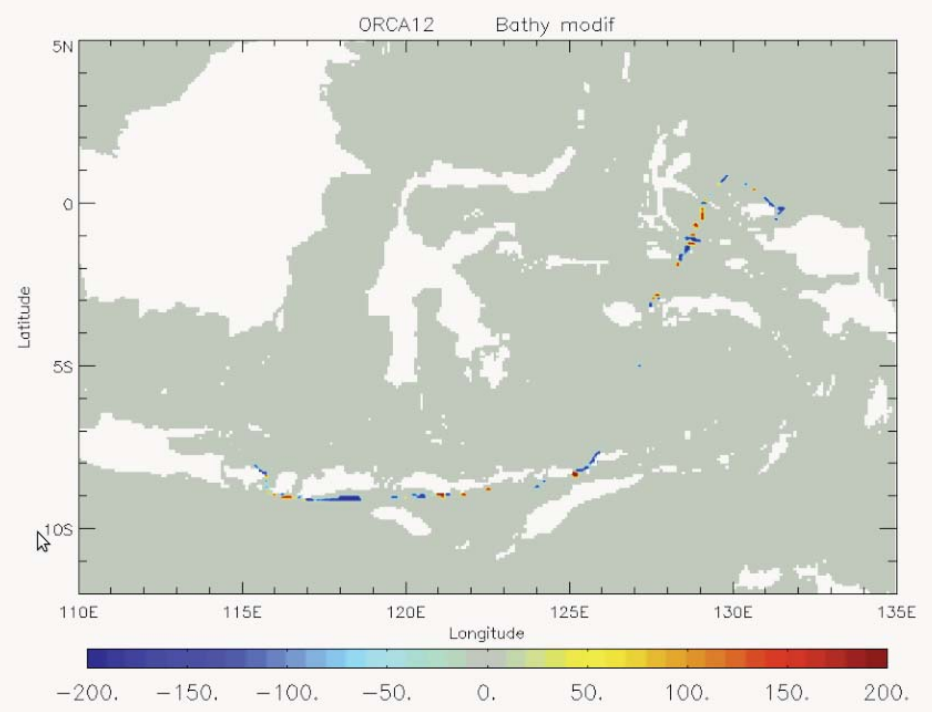

Figure 5: Modification of the bathymetry ORCA12, thanks to the consideration of the data collected during the INDOMIX cruise.

[10] PREVIMER - http://www.previmer.org - [11] MERCATOR OCEAN : http://www.mercator-ocean.fr

Mercator Ocean also used CheckBMG to improve the bathymetry of the Iberian Biscay Irish (IBI, Maraldi *et al.*, 2013; Cailleau *et al.*, 2012) operational system. Indeed some anomalous points (less that a dozen) along the coast of Brittany and in the Irish Sea have been corrected with CheckBMG by reverting those to the GEBCO 1' bathymetry values. In the Gulf of Cadiz, a suspicious mountain at 6.92°W 36.45°N (near PdE Cadiz buoy), has been suppressed by reverting to GEBCO 1' bathymetry in this area. Finally, data compilation from the SWIM project (Zitellini *et al.*, 2009) and data from GMRT (Global Multi-Resolution Topography, Ryan et al 2009, http://www.marine-geo.org/tools/maps_grids.php) has been used to correct the original bathymetry in the Gulf of Cadiz and in the Gibraltar strait. All those corrections were made easily with the use of CheckBMG.

Conclusion

These tools have already proven their operational capability in the community of modelers using MARS3D code. These reliable tools are used either in research or in operational oceanography applications as PREVIMER or MERCATOR. Their compatibility with the C-Arakawa grid and the use of a standard netCDF file format with common conventions make them usable with other oceanic circulation model. These tools belong to the family of pre-processing tools as ROMSTOOLS (Penven *et al.*, 2007) who are designed to facilitate modelers' work.

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