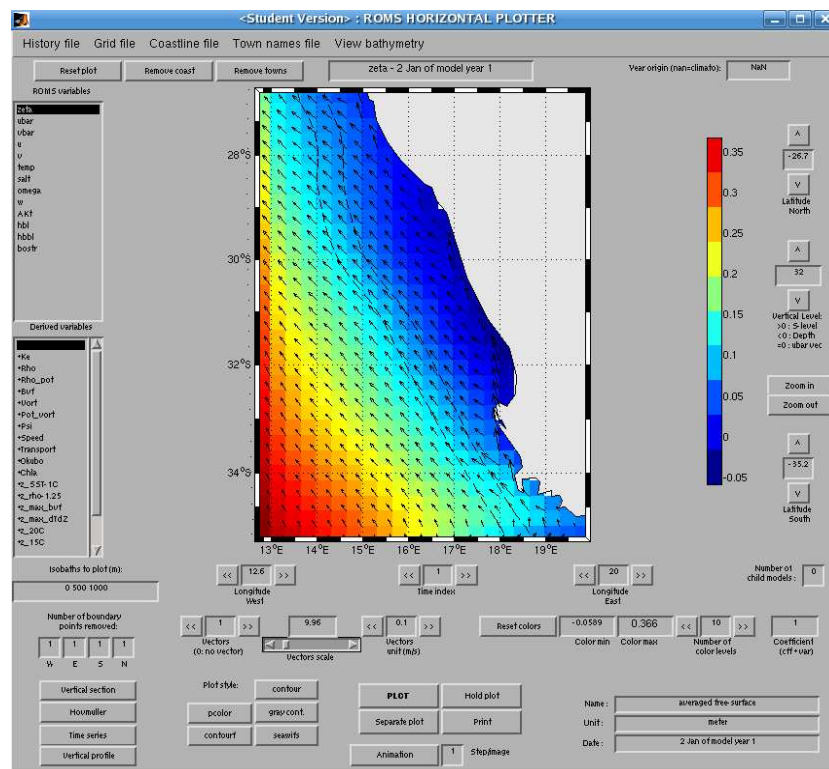


ROMS_AGRIF 2.0 User's Guide

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Introduction

The Regional Ocean Modeling System (ROMS) is a new generation ocean circulation model (Shchepetkin and McWilliams, 2005) that has been specially designed for accurate simulations of regional oceanic systems. The reader is referred to Shchepetkin and McWilliams (2003) and to Shchepetkin and McWilliams (2005) for a complete description of the model. ROMS has been applied for the regional simulation of a variety of different regions of the world oceans (e.g. Blanke et al., 2002; Di Lorenzo et al., 2003; Haidvogel et al., 2000; MacCready et al., 2002; Marchesiello et al., 2003; Penven et al., 2001).

To perform a regional simulation using ROMS, the modeler needs to provide several data files in a specific format: horizontal grid, bottom topography, surface forcing, lateral boundary conditions... He also needs to analyze the model outputs. The tools which are described here have been designed to perform these tasks. The goal is to be able to build a standard regional model configuration in a minimum time.

In the first chapter, the system requirements and the installation process are exposed. A short note on ROMS model is presented in chapter 2. A tutorial on the use of ROMSTOOLS is shown in the third section. Tidal simulations, inter-annual simulations, nesting tools, biology and operational regional modeling are presented in section 4, 5, 6, 7 and 8.

In the second chapter, some details of the IRD version of ROMS new release, named `roms_agrif 2.0`, using the AGRIF nesting procedure are presented. First, the new AGRIF 2-ways nesting procedure implemented in the code is described, then new numerical and physical schemes and parametrization are exposed. Then a changelog section since the last `roms_agrif 1.0` official version is presented. Finally, the `cpp-keys`, parameters and input files are described in details to correctly configure the model options.

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Chapter 1

ROMSTOOLS matlab toolbox

1.0.1 Installation

System requirement

This toolbox has been designed for Matlab. It needs at least 2 Gbytes of disk space. It has been tested on several Matlab versions ranging from Matlab6 to Matlab2006a. It has been mostly tested on Linux workstations, but it could be used on any platform if a NetCDF and a LoadDAP Matlab Mex files are provided. The NetCDF Matlab Mex file is needed to read and write into NetCDF files and it can be found at the web location: <http://mexcdf.sourceforge.net/>. The LoadDAP Matlab Mex file is used to download data from OpenDAP servers for inter-annual and forecast simulations. It can be found at the web location: <http://www.opendap.org/download/ml-structs.html>. The Matlab LoadDAP Mex file provides a way to read any OpenDAP-accessible data into Matlab. Note that the LibDAP library must be installed on your system before installing LoadDAP. Details can be found at the web location: <http://www.opendap.org>. MexCDF and LoadDAP mex files are provided for Linux (system FEDORA 32bits: mexcdf and Opendap_tools/FEDORA ; system CENTOS or FEDORA 64bits: mexnc and Opendap_tools/FEDORA_X64), but they are not working on all the platforms.

All the other necessary Matlab toolboxes (i.e. air-sea, mask, netcdf or m_map...) are included in the ROMSTOOLS package. Global datasets, such as topography (Smith and Sandwell, 1997), hydrography (Conkright et al., 2002) or surface fluxes (Da Silva et al., 1994), are also included.

Getting the files

All the necessary compressed tar files (XXX.tar.gz) containing the Matlab programs, several datasets and other toolboxes and softwares needed by ROMSTOOLS are located at:

http://roms.mpl.ird.fr/Roms_tools/index.html

For the ROMS source code you should download ROMS_AGRIF version V1.1.

Extracting the files

Download all the compressed tar files. Uncompress and untar all the files (gunzip and tar -xvf). You should obtain the following directory tree :

```
Roms_tools
|- Aforc_NCEP
|- Aforc_QuikSCAT
|- air_sea
|- COADS05
|- Compile
|- Diagnostic_tools
|- Documentation
|   |- User_guide
|- Forecast_tools
|- mask
|- mex60
|- mexnc
|   |- tests
|- m_map
|   |- private
|- Nesting_tools
|- netcdf_g77
|- netcdf_ifc
|- netcdf_matlab
|   |- listpick
|   |- ncatt
|   |- ncbrowser
|   |- ncdim
|   |- ncfiles
|   |- ncitem
|   |- ncrec
|   |- nctype
|   |- ncutility
|   |- ncvar
|   |- netcdf
|- netcdf_x86_64
|- Oforc_OGCM
|- Opendap_tools
|   |- FEDORA
|   |- FEDORA_X64
|- Preprocessing_tools
|- Roms_Agrif
|   |- AGRIF_ZOOM
|   |   |- AGRIF_FILES
|   |   |- AGRIF_INC
|   |   |- AGRIF_OBJS
|   |   |- AGRIF_YOURFILES
```



```

|   |   | - LIB.clean
|- Run
|   | - DATA
|   | - FORECAST
|   | - ROMS_FILES
|   | - SCRATCH
|   | - TEST_CASES
|- SeaWifs
|- SST_pathfinder
|- Tides
|- Topo
|   | - Matlab
|- TPX06
|- TPX07
|- Visualization_tools
|- WOA2001
|- WOA2005

```

Definition of the different directories :

- Aforc_NCEP : Scripts for the recovery of surface forcing data (based on NCEP reanalysis) for inter-annual simulations.
- Aforc_QuikSCAT : Scripts for the recovery of wind stress from satellite scatterometer data (QuickSCAT).
- COADS05 : Directory of the surface fluxes global monthly climatology at 0.5° resolution (Da Silva et al., 1994).
- Compile : Empty scratch directory for ROMS compilation.
- Diagnostic_tools : A few Matlab scripts for animations and basic statistical analysis.
- Documentation : Location of the ROMSTOOLS user guide.
- Forecast_tools : Scripts for the generation of an operational modeling system
- mask : Land mask edition toolbox developed by A.Y. Shcherbina.
- mex60 : Matlab NetCDF interface for 32 bits Linux architectures.
- mexnc : Matlab NetCDF interface for 64 bits Linux architectures.
- **mexnc32** :
- **mexnc64** :
- m_map : The Matlab mapping toolbox (<http://www2.ocgy.ubc.ca/~rich/map.html>).
- Nesting_tools : Preprocessing tools used to prepare nested models.
- netcdf_g77 : The NetCDF Fortran library for Linux, compiled using g77 (<http://www.unidata.ucar.edu/packages/netcdf/index.html>).

- netcdf_ifc : The NetCDF Fortran library for Linux, compiled with ifort. The Intel Fortran Compiler (ifort) is available at <http://www.intel.com/software/products/compilers/flin/noncom.htm>.
- netcdf_matlab : The Matlab NetCDF toolbox (http://woodshole.er.usgs.gov/staffpages/cdenham/public_html/MexCDF/nc4ml5.html).
- netcdf_x86_64 : The NetCDF Fortran library for Linux, compiled with ifort on a 64 bits architecture.
- Oforc_OGCM : Scripts for the recovery of initial and lateral boundary conditions from global OGCMs (SODA (Carton et al., 2005) or ECCO (Stammer et al., 1999)) for inter-annual simulations.
- Opendap_tools : LoadDAP mexcdf and several scripts to automatically download data over the Internet.
- Preprocessing_tools : Preprocessing Matlab scripts (make_grid.m, make_forcing, etc...).
- Roms_Agrif : ROMS Fortran sources.
- Run : Working directory. This is where the ROMS input files are generated and where the model is running.
- SeaWifs : surface chlorophyll-a climatology based on SeaWifs observations.
- SST_pathfinder : Directory of a higher resolution SST climatology (Reynolds and Smith, 1994) for the thermal correction term.
- Tides : Matlab routines to prepare ROMS tidal simulations. Tidal data are derived from the Oregon State University global models of ocean tides TPXO6 and TPXO7 (Egbert and Erofeeva, 2002): <http://www.oce.orst.edu/research/po/research/tide/global.html>.
- Topo : Location of the global topography dataset at 2' resolution (Smith and Sandwell, 1997). Original data can be found at: http://topex.ucsd.edu/cgi-bin/get_data.cgi
- TPXO6 : Directory of the global model of ocean tides TPXO6 (Egbert and Erofeeva, 2002).
- TPXO7 : Directory of the global model of ocean tides TPXO7 (Egbert and Erofeeva, 2002).
- Visualization_tools : Matlab scripts for the ROMS visualization graphic user interface.
- WOA2001 : World Ocean Atlas 2001 global dataset (monthly climatology at 1° resolution) (Conkright et al., 2002).
- WOA2005 : World Ocean Atlas 2005 global dataset

1.0.2 LibDAP and LoadDAP

It is sometimes difficult to compile LoadDAP. LibDAP must be installed before installing LoadDAP. You have to declare the LibDAP binary and library in your `./bashrc` with the command `PATH` and `LD_LIBRARY_PATH`. Once, compile and install LoadDAP.

Here are a few instructions for the installation of these libraries:

- Download libDAP and loadDAP tar.gz version at the web location <http://www.opendap.org>
- To build the libDAP library, follow these steps:

- log you as a root
- Uncompress and untar the file `libdap.tar.gz` (`gunzip` and `tar -xvf`)
- `>: cd libdap_directory`
- Type `'./configure'` at the prompt. Some libraries must be installed on your system to successfully run `configure` and build libDAP library : `libcurl` (<http://curl.haxx.se/>) and `libxml2` (<http://xmlsoft.org/>).

Example:

```
checking for a BSD-compatible install... /usr/bin/install -c
checking whether build environment is sane... yes
checking whether make sets (MAKE)... yes
checking build system type... i686-pc-linux-gnu
checking host system type... i686-pc-linux-gnu
checking for gawk... (cached) mawk
checking for g++... g++
checking for C++ compiler default output file name... a.out
...
config.status: dods-datatypes.h is unchanged
config.status: executing depfiles commands
```

- Type `'make'` to build the library.

Example :

```
make[1]: Entering directory '/home/tropic/tan/soft/libdap-3.6.2'
Making all in gl
make[2]: Entering directory '/home/tropic/tan/soft/libdap-3.6.2/gl'
make all-am
make[3]: Entering directory '/home/tropic/tan/soft/libdap-3.6.2/gl'
...
```

- Type `'make check'` to run the tests. To pass this step you must have DejaGNU framework (GNU FTP mirror list: <http://www.gnu.org/prep/ftp.html>).

Example :

```
make[1]: Entering directory '/home/tropic/tan/soft/libdap-3.6.2/gl'
dejagnu_driver.sh
...
Test Run By tan on Thu Jul 19 11:19:02 2007
Native configuration is i686-pc-linux-gnu
===== das-test tests =====
Running ...
===== das-test Summary =====
===== dds-test tests =====
Running ...
===== dds-test Summary =====
===== expr-test tests =====
Running ...
===== expr-test Summary =====
PASS: dejagnu_driver.sh
=====
All 1 tests passed
=====
make[2]: Leaving directory '/home/tropic/tan/soft/libdap-3.6.2/tests'
make[1]: Leaving directory '/home/tropic/tan/soft/libdap-3.6.2/tests'
```

- Type 'make install' to install the library. By default the files are installed under /usr/local/lib/. You can specify a different root directory using the following control : 'make install root_directory'.
- Go to the .bashrc and add
EXPORT LD_LIBRARY_PATH=\$LD_LIBRARY_PATH : root_directory.'
- The installation of the loadDAP library is done as for libDAP. By default the files are installed under /usr/local/share/.
- Go in the .dodsrc file, add the PROXY_SERVER configuration, if needed, for example PROXY_SERVER http,proxy.legos.obs-mip.fr:3128

1.0.3 Future plans

- A graphic user interface could be useful for the preprocessing tools.
- There is need for an improvement of the extrapolation and interpolation methods.

1.0.4 Warnings

- Since Geostrophy is used to obtain the horizontal currents for the lateral boundary conditions, this method should be applied with care close to the Equator. An ex-

trapolation of the currents outside an equatorial band (2°S - 2°N) is performed to get an approximation of the equatorial currents.

- On extended grids, the objective analysis used for data extrapolation can be relatively costly in memory and CPU time. The "nearest" Matlab function that is less costly can be used instead. If the computer starts to swap, you should think of reducing the dimension of your model's domain.

1.1 Tutorial : the Southern Benguela example

This section presents the essential steps for preparing and running a regional ROMS simulation. This is done following the example of a model of the Southern Benguela at low resolution and using climatological forcing at surface and boundaries.

1.1.1 Getting started : Processing input files

Once the installation has been successful, launch a Matlab session in the directory: `~/Roms_tools/Run`. Run the `start.m` script to set the Matlab paths for this session.

In this step of this installation, you have to know a few things concerning your matlab setup and your computer environment:

- What is the architecture of my machine 32 or 64 bits ? For that do `uname -a`.
- What are the native matlab installation library that I have ?
- Do I need to install manually the netcdf library ?
- Do I need to add manually the `m_map` library ? For these questions, edit your matlab path with the matlab command **path**.

In the `Roms_tools`, some netcdf libraries for matlab are provided :

- `mex60` : matlab12 (old) and 32 bits architecture
- `mexnc` : matlab7 and 64 bits architecture
- `mexnc32` : matlab7 and 32 bits architecture... to do
- `mexnc64` : matlab7 and 64 bits architecture... to do

In the `Roms_tools`, some "opendap" bins and libraries are also provided :

- `Opendap_tools/FEDORA` : LibDAP and LoadDAP bin and library for Fedora Linux distribution, 32 bits architecture
- `Opendap_tools/FEDORA_X64` : Same for 64 bits architecture.

However, if your Linux distribution differs from Fedora, the best is to compile and install by your own the LibDAP and LoadDAP.

You are now ready to create a new configuration. It is important to respect the order of the following preprocessing steps: `make_grid`, `make_forcing`, `make_clim`. For all the preprocessing steps, there is only one file to edit : `~/Roms_tools/Run/romstools_param.m`. This file contains the necessary parameters for the generation of the ROMS input NetCDF files. The first section in `romstools_param.m` defines the general parameters, such as title, working directories or file names:

```
%%%%%%%%%%%%%%
%
% 1- General parameters
```

```

%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
% ROMS title names and directories
%
ROMS_title = 'Benguela Test Model';
ROMS_config = 'Benguela';
ROMSTOOLS_dir = '../';
RUN_dir=[ROMSTOOLS_dir,'Run/'];
ROMS_files_dir=[RUN_dir,'ROMS-FILES/'];
%
% ROMS file names (grid, forcing, bulk, climatology, initial)
%
grdname=[ROMS_files_dir,'roms_grd.nc'];
frcname=[ROMS_files_dir,'roms_frc.nc'];
blkname=[ROMS_files_dir,'roms_blk.nc'];
clmname=[ROMS_files_dir,'roms_clm.nc'];
iname=[ROMS_files_dir,'roms_ini.nc'];
oaname = [ROMS_files_dir,'roms_oa.nc']; % oa file : intermediate file not used
% in roms simulations
bryname=[ROMS_files_dir,'roms_bry.nc'];
Zbryname=[ROMS_files_dir,'roms_bry_Z.nc']; % Zbry file: intermediate file not used
% in roms simulations
%
frc_prefix=[ROMS_files_dir,'roms_frc']; % generic bulk forcing file name
% for inter-annual roms simulations (NCEP or GFS)
blk_prefix=[ROMS_files_dir,'roms_blk']; % generic forcing file name
% for inter-annual roms simulations (NCEP or GFS)
%
% Objective analysis decorrelation scale [m]
% (if Roa=0: simple extrapolation method; crude but much less costly)
%
%Roa=300e3;
Roa=0;
%
interp_method = 'cubic'; % Interpolation method: 'linear' or 'cubic'
%
makeplot = 1; % 1: create a few graphics after each preprocessing step
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

```

Variables description:

- title='Benguela Test Model' : General title. You can give any name you want for your configuration.
- ROMS_config = 'Benguela' : Name of the configuration. This is used for the storage of NCEP or OGCM data for a specific configuration.

- ROMSTOOLS_dir = '../' : "Roms_tools" directory.
- RUN_dir=[ROMSTOOLS_dir,'Run/'] : Roms_tools/Run directory. This is where all the work is done.
- ROMS_files_dir=[RUN_dir,'ROMS_FILES/'] : Roms_tools/Run/ROMS_FILES/ directory. This is where ROMS input NetCDF files are stored.
- grdname=[ROMS_files_dir,'roms_grd.nc'] : Name of the ROMS input NetCDF grid file. This is where the horizontal grid parameters are stored. In general, we follow the style : XXX_grd.nc.
- frcname=[ROMS_files_dir,'roms_frc.nc'] : : Name of the ROMS input NetCDF forcing file. This is where the surface forcing variables (such as wind stress) are stored. In general, we follow the style : XXX_frc.nc.
- blkname=[ROMS_files_dir,'roms_blk.nc'] : Name of the ROMS input NetCDF bulk file. This is where the atmospheric variables used for the bulk parametrization (such as air temperature) are stored. In general, we follow the style : XXX_blk.nc.
- clmname=[ROMS_files_dir,'roms_clm.nc'] : Name of the ROMS input NetCDF climatology file. This is where ROMS prognostic variables (u,v, temp, salt, ubar, vbar, zeta) for lateral boundary and interior nudging are stored. This file can be large because variables are stored for all the ROMS grid interior points. It is called "a climatology file" because this was the file used in the past for the restoring of the ROMS solution towards an in-situ climatology (such as Levitus for example). In general, we follow the style : XXX_clm.nc.
- ininame=[ROMS_files_dir,'roms_ini.nc'] : Name of the ROMS input NetCDF initial file. This is where ROMS prognostic variables (u,v, temp, salt, ubar, vbar, zeta) are stored for the initial conditions. In general, we follow the style : XXX_ini.nc.
- oaname =[ROMS_files_dir,'roms_oa.nc'] : Name of an intermediate file which is not used by ROMS. This is equivalent to the climatology file, but on a z vertical coordinate. Firstly, the variables are horizontally interpolated to create a roms_oa.nc file (a OA file). Then, they are vertically interpolated on the ROMS s-coordinate for the climatology file. In general, we follow the style : XXX_oa.nc.
- bryname=[ROMS_files_dir,'roms_bry.nc'] : Name of the ROMS input NetCDF boundary file. This is an alternative of the climatology file. In this case, variables are only stored for the lateral boundaries. In general, we follow the style : XXX_bry.nc.
- Zbryname=[ROMS_files_dir,'roms_bry_Z.nc'] : Intermediate file on a z coordinate for the boundary file. In general, we follow the style : XXX_bry_Z.nc.
- frc_prefix=[ROMS_files_dir,'roms_frc'] : First part of the forcing file names in the case of inter_annual simulations. In this case, a separate file is created for each month. For example, a forcing file based on NCEP for January 2000 is : roms_frc_NCEP_Y2000M1.nc
- blk_prefix=[ROMS_files_dir,'roms_blk'] : First part of the bulk file names in the case of inter_annual simulations. In this case, a separate file is created for each month. For example, a bulk file based on NCEP for January 2000 is : roms_blk_NCEP_Y2000M1.nc

- Roa=0 : Decorrelation length scale in meters for the objective analysis (300 km is a reasonable value for the employed datasets). If Roa=0, the "nearest" Matlab extrapolation method is used instead of an objective analysis. This is much less costly, but the results might be at a lower quality.
- interp_method = 'cubic' : Horizontal interpolation method used after the objective analysis. It can be linear or cubic.
- makeplot = 1 : Select to generate images after each step of the preprocessing.

1.1.2 Building the grid

The part of the file romstools_param.m that you should be edit is :

```

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
% 2-Grid parameters
% used by make_grid.m (and others..)
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
% Grid dimensions:
%
lonmin = 12.3; % Minimum longitude [degree east]
lonmax = 20.45; % Maximum longitude [degree east]
latmin = -35.5; % Minimum latitude [degree north]
latmax = -26.5; % Maximum latitude [degree north]
%
% Grid resolution [degree]
%
dl = 1/3;
%
% Number of vertical Levels (! should be the same in param.h !)
%
N = 32;
%
% Vertical grid parameters (! should be the same in roms.in !)
%
theta_s = 6.;
theta_b = 0.;
hc = 10.;
%
% Minimum depth at the shore [m] (depends on the resolution,
% rule of thumb: dl=1, hmin=300, dl=1/4, hmin=150, ...)
% This affect the filtering since it works on grad(h)/h.
%
hmin = 75;
%
% Maximum depth at the shore [m] (to prevent the generation

```

```

% of too big walls along the coast)
%
hmax_coast = 500;
%
% Topography netcdf file name (ETOPO 2 or any other netcdf file
% in the same format)
%
topofile = [ROMSTOOLS_dir,'Topo/etopo2.nc'];
%
% Slope parameter (r=grad(h)/h) maximum value for topography smoothing
%
rtarget = 0.25;
%
% Number of pass of a selective filter to reduce the isolated
% seamounts on the deep ocean.
%
n_filter_deep_topo=4;
%
% Number of pass of a single hanning filter at the end of the
% smoothing procedure to ensure that there is no 2DX noise in the
% topography.
%
n_filter_final=2;
%
% GSHSS user defined coastline (see m_map)
% XXX_f.mat Full resolution data
% XXX_h.mat High resolution data
% XXX_i.mat Intermediate resolution data
% XXX_l.mat Low resolution data
% XXX_c.mat Crude resolution data
%
coastfileplot = 'coastline_l.mat';
coastfilemask = 'coastline_l_mask.mat';

```

Variables description:

- lonmin = 12.3 : Western limit of the grid in longitude $[-360^\circ, 360^\circ]$. The grid is rectangular in latitude/longitude.
- lonmax = 20.45 : Eastern limit $[-360^\circ, 360^\circ]$. Should be superior to lonmin.
- latmin = -35.5 : Southern limit of the grid in latitude $[-90^\circ, 90^\circ]$.
- latmax = -26.5 : Northern limit $[-90^\circ, 90^\circ]$. Should be superior to latmin.
- l = 1/3 : Grid longitude resolution in degrees. The latitude spacing is deduced to obtain an isotropic grid using the relation: $d\phi = dl \cos(\phi)$.
- N = 32 : Number of vertical levels. Warning! N has to be also defined in the file : `~/Roms_tools/Run/param.h` before compiling the model.

- `theta_s = 6.` : Vertical S-coordinate surface stretching parameter. When building the climatology and initial ROMS files, we have to define the vertical grid. Warning! The different vertical grid parameters should be identical in this file and in the ROMS input file (i.e. `~/Roms_tools/Run/roms.in`). This is a serious cause of bug. The effects of `theta_s`, `theta_b`, `hc`, and `N` can be tested using the Matlab script : `~/Roms_tools/Preprocessing_tools/test_vgrid.m`.
- `theta_b = 0.` : Vertical S-coordinate bottom stretching parameter.
- `hc = 10.` : Vertical S-coordinate H_c parameter. It gives approximately the transition depth between the horizontal surface levels and the bottom terrain following levels. It should be inferior to `hmin`.
- `hmin = 75` : Minimum depth in meters. The model depth is cut at this level to prevent, for example, the occurrence of model grid cells without water. This does not influence the masking routines. At lower resolution, `hmin` should be quite large (for example 150m for `dl=1/2`). Otherwise, since topography smoothing is based on $\frac{\nabla h}{2h}$, the bottom slopes can be totally eroded.
- `hmax_coast = 500` : Maximum depth under the mask. It prevents selected isobaths (here 500 m) to go under the mask. If this is the case, this could be a source of problems for western boundary currents (for example).
- `topofile = [ROMSTOOLS_dir,'Topo/etopo2.nc']` : Default topography file. We are using here `etopo2` (Smith and Sandwell, 1997).
- `rtarget = 0.25` : This variable controls the maximum value of the r -parameter that measures the slope of the sigma layers (Beckmann and Haidvogel, 1993):

$$r = \frac{\nabla h}{2h} = \frac{h_{+1/2} - h_{-1/2}}{h_{+1/2} + h_{-1/2}}$$

To prevent horizontal pressure gradients errors, well known in terrain-following coordinate models (Haney, 1991), realistic topography requires some smoothing. Empirical results have shown that reliable model results are obtained if r does not exceed 0.2.

- `n_filter_deep_topo=4` : Number of pass of a Hanning filter to prevent the occurrence of noise and isolated seamounts on deep regions.
- `n_filter_final=2` : Number of pass of a Hanning filter at the end of the smoothing process to be sure that no noise is present in the topography.
- `coastfileplot = 'coastline_l.mat'` : Binary GSHSS coastal file used by `m_map` for graphical purposes. The letter before ".mat" selects the coastline resolution. f: Full resolution, h: High resolution, i: Intermediate resolution, l: Low resolution c: Crude resolution.
- `coastfilemask = 'coastline_l_mask.mat'` : Binary file used for the coastline in the masking toolbox.

Save romstools_param.m and run make_grid in the Matlab session :

```
>>  
>> make_grid
```

You should obtain in the Matlab session:

Making the grid: ../Run/ROMS_FILES/roms_grd.nc

Title: Benguela Test Model

Resolution: 1/3 deg

Create the grid file...

LLm = 23

MMm = 31

Fill the grid file...

Compute the metrics...

Min dx=30.1583 km - Max dx=33.1863 km

Min dy=30.2091 km - Max dy=33.057 km

Fill the grid file...

Add topography...

ROMS resolution : 31.7 km

Topography data resolution : 3.44 km

Topography resolution halved 4 times

New topography resolution : 54.8 km

Processing coastline.l.mat ...

Do you want to use editmask ? y,[n]

Apply a filter on the Deep Ocean to remove the isolated seamounts :

4 pass of a selective filter.

Apply a selective filter on log(h) to reduce grad(h)/h :

13 iterations - rmax = 0.24879

Smooth the topography a last time to prevent 2DX noise:

2 pass of a hanning smoother.

Write it down...

Do a plot...

```
>>
```

You should keep the values of LLm and MMm during the process. They will be necessary for the ROMS parameter file ~/Roms_tools/Run/param.h. In this test case, LLm0 = 23 and MMm0 = 31.

During the grid generation process, the question "Do you want to use editmask ? y,[n]" is asked. The default answer is n (for no). If the answer is y (for yes), editmask, the graphic interface developed by A.Y.Shcherbina, will be launched to manually edit the mask (Note that, for the moment, editmask is not working with matlab7 and mexnc). Otherwise the mask is generated from the unfiltered topography data. A procedure prevents the existence of isolated land (or sea) points.

Figure (1.1) presents the bottom topography obtained with make_grid.m for the Southern Benguela example. Note that at this low resolution ($1/3^\circ$), the topography has been strongly smoothed.

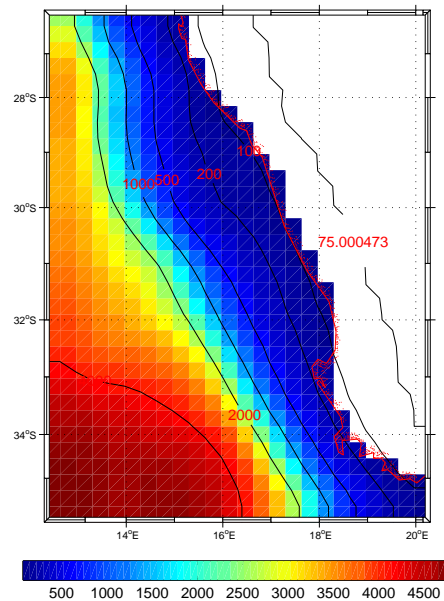


Figure 1.1: Result of make_grid.m for the Benguela example

1.1.3 Getting the wind and other surface fluxes

The next step is to create the file containing the different surface fluxes. The part of the file romstools_param.m that you should edit is :

```
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% 3-Surface forcing parameters
% used by make_forcing.m and by make_bulk.m
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% COADS directory (for climatology runs)
%
coads_dir=[ROMSTOOLS_dir,'COADS05/'];
%
% COADS time (for climatology runs)
%
coads_time=(15:30:345); % days: middle of each month
```

```

coads_cycle=360; % repetition of a typical year of 360 days
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
% 3.1 Surface forcing parameters
% used by pathfinder_sst.m
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
pathfinder_sst_name=[ROMSTOOLS_dir,...
'SST_pathfinder/climato_pathfinder.nc'];

```

Variables description:

- `coads_dir`=[ROMSTOOLS_dir,'COADS05/'] : Directory where the global atlas of surface marine data at 1/2° resolution (Da Silva et al., 1994) is located.
- `coads_time`=(15:30:345) : Time in days for the monthly climatology. It corresponds to the middle of each month. ROMS uses this time to interpolate linearly the forcing variables in time.
- `coads_cycle`=360 : Duration on which the forcing variables are cycled. Here, for the sake of simplicity, we are running the model on a repeating climatological year of 360 days.
- `pathfinder_sst_name`=[ROMSTOOLS_dir,'SST_pathfinder/climato_pathfinder.nc'] : Directory of the monthly climatology of sea surface temperature from Pathfinder satellite observations (Casey and Cornillon, 1999). This can be used as an alternative of Da Silva et al. (1994) SST.

Save `romstools_param.m` and run `make_forcing` in the Matlab session :

```

>>
>> make_forcing

```

You should obtain :

Benguela Test Model

Read in the grid...

Create the forcing file...

Getting `taux` for time index 1

Getting `tauy` for time index 1

...

Make a few plots...

```

>>

```

This program can take a relatively long time to process all the forcing variables. Figure (1.2) presents the wind stress vectors and wind stress norm obtained from the global atlas of surface marine data at $1/2^\circ$ resolution (Da Silva et al., 1994) at 4 different periods of the year. Da Silva et al. (1994) sea surface temperature (SST) is used for the restoring term (dQdSST) in the heat flux calculation. To improve the model solution it is possible to use a SST climatology at a finer resolution (9.28 km) (Casey and Cornillon, 1999). To do so, you can run `pathfinder_sst.m` in the Matlab session :

```
>>
>> pathfinder_sst
```

You should obtain :

```
... Month index: 1
... Month index: 2
...
>>
```

For the surface forcing, instead of directly prescribing the fluxes, it is possible to use a bulk formula to generate the surface fluxes from atmospheric variables during the model run. In this case, ROMS needs to be recompiled with the `BULK_FLUX` cpp key defined. To generate the bulk forcing file, you need to run `make_bulk` in the Matlab session :

```
>>
>> make_bulk
```

You should obtain :

Benguela Test Model

Read in the grid...

Create the bulk forcing file...

Getting sat for time index 1

Getting sat for time index 2

...

Make a few plots...

```
>>
```

1.1.4 Getting the initial and the lateral boundary conditions

The last preprocessing step consists in generating the files containing the necessary informations for the ROMS initial and lateral open boundaries conditions. This script generates

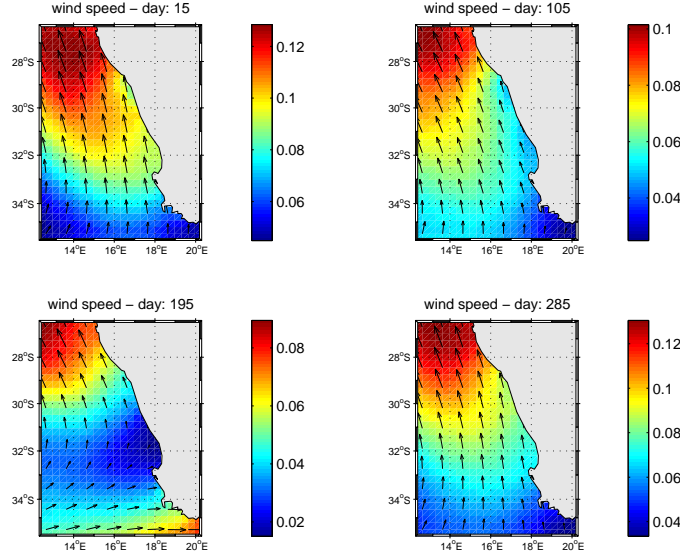


Figure 1.2: Wind stress $[\text{N.m}^{-2}]$ obtained using `make_forcing.m` for the Benguela example.

two files : the climatology file (XXX_clm.nc) which gives the lateral boundary conditions, and the initial conditions file (XXX_ini.nc). The part which should be edited by the user in the file `romstools_param.m` is:

```
%%%%%%%%%%%%%%
%
% 4-Open boundaries and initial conditions parameters
% used by make_clim.m, make_biol.m, make_bry.m
%
%%%%%%%%%%%%%%
% Open boundaries switches (! should be consistent with cppdefs.h !)
%
obc = [1 1 1 1]; % open boundaries (1=open , [S E N W])
%
% Level of reference for geostrophy calculation
%
zref = -1000;
%
% Switches for selecting what to process in make_clim (1=ON)
% (and also in make_OGCM.m and make_OGCM_frcst.m)
makeini=1; %1: process initial data
makeclim=1; %1: process lateral boundary data
makebry=0; %1: process boundary data
%
makeoa=1; %1: process oa data (intermediate file)
makeZbry=0; %1: process data in Z coordinate
%
insitu2pot=1; %1: convert in-situ temperature into potential temperature
%
```



```

% Day of initialization for climatology experiments (=0 : 1st January 0h)
%
tini=0;
%
% World Ocean Atlas directory (WOA2001 or WOA2005)
%
woa_dir=[ROMSTOOLS_dir,'WOA2005/'];
%
% Surface chlorophyll seasonal climatology (WOA2001 or SeaWifs)
%
chla_dir=[ROMSTOOLS_dir,'SeaWifs/'];
%
% Set times and cycles for the boundary conditions:
% monthly climatology
%
woa_time=(15:30:345); % days: middle of each month
woa_cycle=360; % repetition of a typical year of 360 days
%
```

Variables description:

- `obc=[1 1 1 1]` : Switches to open (1=open) or close (0=wall) the lateral boundaries [South East North West]. This is used for the application of mass enforcement. Be aware, this should be compatible with the open boundary CPP-switches in the file `~/Roms_tools/Run/cppdefs.h`.
- `zref=-1000` : Depth [meters] of the level of no motion for the geostrophic velocities calculation.
- `makeini=1` : Switch to define if the initial file (`roms_ini.nc`) is generated. Should be 1.
- `makeclim=1` : Switch to define if the climatology (lateral boundary conditions) file (`roms_clm.nc`) is generated. Should be 1.
- `makeoa=1` : Switch to define if the OA (objective analysis; `roms_oa.nc`) file is generated. This should be 1. The OA files are intermediate files where hydrographic data are stored on a ROMS horizontal grid but on a z vertical grid. The transformation into S-coordinate is done later. This file is not used by ROMS.
- `makebry=1` : Switch to define if the boundary file (`roms_bry.nc`) is generated. Used only with `make_bry`.
- `makeZbry=1` : Switch to define if the boundary intermediate file on a z coordinate (`roms_bry_Z.nc`) is generated. Used only with `make_bry`.
- `insitu2pot=1` : Switch defined if it is in-situ temperature that is provided. In this case, in-situ temperature is converted into potential temperature.
- `tini=0` : Day of initialization in climatology experiments (15 = January 15).

- `woa_dir=[ROMSTOOLS_dir,'WOA2005/']` : Directory where the World Ocean Atlas 2005 climatology (Conkright et al., 2002) is located. The World Ocean Atlas 2001 climatology can also be used.
- `chla_dir=[ROMSTOOLS_dir,'SeaWifs/']` : Directory of the surface chlorophyll seasonal climatology.
- `woa_time=(15:30:345)` : Time in days for the WOA monthly climatology. It corresponds to the middle of each month. ROMS uses this variable to interpolate linearly the climatology variables in time.
- `woa_cycle=360` : Duration on which the climatology variables are cycled. Here, for the sake of simplicity, we are running the model on a repeating climatological year of 360 days.

Save `romstools_param.m` and run `make_clim` in the Matlab session :

```
>>
>> make_clim
```

You should obtain :

Making the clim: `../Run/ROMS_FILES/roms_clm.nc`

Title: Benguela Test Model

Read in the grid...

Create the climatology file...

Creating the file : `../Run/ROMS_FILES/roms_clm.nc`

...

Make a few plots...

```
>>
```

This program can also take quite a long time to run. Figure (1.3) presents 4 different sections of temperature for the initial condition file for the Benguela example. The sections are in the X-direction (East-West), the first section is for the Southern part of the domain and the last one is for the Northern part of the domain.

An alternative of using a climatology file is to create a boundary file. In this case, only boundary values are stored. The cpp key `FRC_BRY` should be defined and ROMS recompiled. Run `make_bry` in the Matlab session :

```
>>
>> make_bry
```

You should obtain :

Making the file: `../Run/ROMS_FILES/roms_bry.nc`

Title: Benguela Test Model

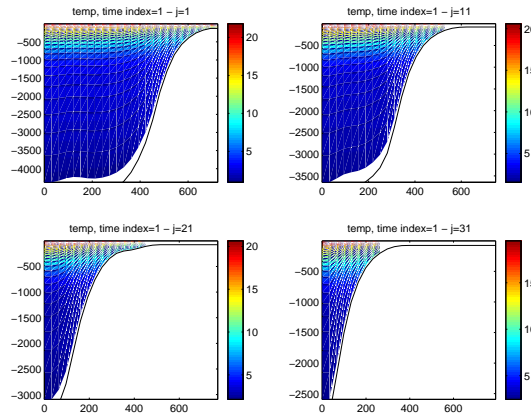


Figure 1.3: Result of make_clim.m for the Benguela example

Read in the grid...

...

1.1.5 Compiling the model

Once all the netcdf data files are ready (i.e. XXX_grd.nc, XXX_frc.nc, XXX_ini.nc, and XXX_clm.nc), we can prepare ROMS for compilation. All is done in the `~/Roms_tools/Run/` directory.

Parameters of the configuration : param.h

Edit the file `~/Roms_tools/Run/param.h`. The line which needs to be changed is:

```
# elif defined BENGUELA_LR
    parameter (LLm0=41, MMm0=42, N=32) ! < -- Southern Benguela Test Case
# else
```

These are the values of the model grid size: LLm0 points in the X direction, MMm0 points in the Y direction and N vertical levels. LLm0 and MMm0 are given by running `make_grid.m`, and N is defined in `romstools-param.m`. The `param.h` parameters are described in detail in section 2.4

Numerical and physical options : cppdefs.h

The second file to edit is `~/Roms_tools/Run/cppdefs.h`. This file defines the CPP keys that are used by the C-preprocessor when compiling ROMS. The C-preprocessor selects the different parts of the Fortran code which needs to be compiled depending on the defined CPP options. These options are separated in two parts (the basic option keys and the advanced options keys) in `cppdefs.h`. All the keys and their organization are described in section 2.5.

Compilation script : jobcomp

ROMS can be compiled by running the UNIX tcsh script `~/Roms_tools/Run/jobcomp`. Jobcomp should be able to recognize your system. It has been tested on Linux, IBM, Sun and Compaq systems. On Linux PCs, the default compiler is the GNU g77, but it is possible to uncomment specific lines in jobcomp to use g95 or ifort. The latter is mandatory when using AGRIF and/or OPEN_MP. When changing the compiler you should provide a corresponding NetCDF library. Once the compilation is done, you should obtain a new executable (roms) in the `~/Roms_tools/Run` directory. ROMS should be recompiled each time `param.h` or `cppdefs.h` are changed.

1.1.6 Running the model

Edit the input parameter file: `~/Roms_tools/Run/roms.in`. The vertical grid parameters (THETA_S, THETA_B, HC) should be identical to the ones in `romstools_param.m`. Otherwise, the other default values should not be changed. The definition of all the input variables is given at the start of each ROMS simulation. To run the model, type in directory `~/Roms_tools/Run/` : `./roms roms.in`. The description of the namelist `roms.in` is described in details in section 2.6

On the screen, you should check the `Cu_max` parameter: if it is greater than 1 you are violating the CFL criterion. In this case, you should reduce the time step.

Example of model run:

```
> : ./roms roms.in
```

You should obtain :

Southern Benguela

480 ntimes Total number of timesteps for 3D equations.

5400.00 dt Timestep [sec] for 3D equations

60 ndtfast Number of 2D timesteps within each 3D step.

1 ninfo Number of timesteps between runtime diagnostics.

6.000E+00 theta_s S-coordinate surface control parameter.

0.000E+00 theta_b S-coordinate bottom control parameter.

1.000E+01 Tcline S-coordinate surface/bottom layer width used in vertical coordinate stretching, meters.

Grid File: ROMS_FILES/roms_grd.nc

Forcing Data File: ROMS_FILES/roms_frc.nc

Bulk Data File: ROMS_FILES/roms_blk.nc

Climatology File: ROMS_FILES/roms_clm.nc

Initial State File: ROMS_FILES/roms_ini.nc Record: 1

Restart File: ROMS_FILES/roms_rst.nc nrst = 480 rec/file: -1

History File: ROMS_FILES/roms_his.nc Create new: T nwrt = 480 rec/file = 0

1 ntsavg Starting timestep for the accumulation of output time-averaged data.

48 navg Number of timesteps between writing of time-averaged data into averages file.

Averages File: ROMS_FILES/roms_avg.nc rec/file = 0

Fields to be saved in history file: (T/F)

T write zeta free-surface.
F write UBAR 2D U-momentum component.
F write VBAR 2D V-momentum component.
F write U 3D U-momentum component.
F write V 3D V-momentum component.
F write T(1) Tracer of index 1.
F write T(2) Tracer of index 2.

F write RHO Density anomaly.
F write Omega Omega vertical velocity.
F write W True vertical velocity.
F write Akv Vertical viscosity.
F write Akt Vertical diffusivity for temperature.
F write Aks Vertical diffusivity for salinity.
F write Hbl Depth of KPP-model boundary layer.
F write Bostr Bottom Stress.

Fields to be saved in averages file: (T/F)

T write zeta free-surface.
T write UBAR 2D U-momentum component.
T write VBAR 2D V-momentum component.
T write U 3D U-momentum component.
T write V 3D V-momentum component.
T write T(1) Tracer of index 1.
T write T(2) Tracer of index 2.

F write RHO Density anomaly
T write Omega Omega vertical velocity.
T write W True vertical velocity.
F write Akv Vertical viscosity
T write Akt Vertical diffusivity for temperature.
F write Aks Vertical diffusivity for salinity.
T write Hbl Depth of KPP-model boundary layer
T write Bostr Bottom Stress.
1025.0000 rho0 Boussinesq approximation mean density, kg/m3.
0.000E+00 visc2 Horizontal Laplacian mixing coefficient [m2/s]
for momentum.
0.000E+00 tnu2(1) Horizontal Laplacian mixing coefficient (m2/s)
for tracer 1.
0.000E+00 tnu2(2) Horizontal Laplacian mixing coefficient (m2/s)
for tracer 2.
0.000E+00 rdrg Linear bottom drag coefficient (m/si).
0.000E+00 rdrg2 Quadratic bottom drag coefficient.
1.000E-02 Zob Bottom roughness for logarithmic law (m).
1.000E-04 Cdb_min Minimum bottom drag coefficient.
1.000E-01 Cdb_max Maximum bottom drag coefficient.

1.00 gamma2 Slipperiness parameter: free-slip +1, or no-slip -1.
1.00E+05 x_sponge Thickness of sponge and/or nudging layer (m)
800.00 v_sponge Viscosity in sponge layer (m2/s)
1.157E-05 tauT_in Nudging coefficients [sec⁻¹]
3.215E-08 tauT_out Nudging coefficients [sec⁻¹]
1.157E-06 tauM_in Nudging coefficients [sec⁻¹]
3.215E-08 tauM_out Nudging coefficients [sec⁻¹]

Activated C-preprocessing Options:

REGIONAL
BENGUELA
OBC_EAST
OBC_WEST
OBC_NORTH
OBC_SOUTH
SOLVE3D
UV_COR
UV_ADV
CURVGRID
SPHERICAL
MASKING
AVERAGES
AVERAGES_K
SALINITY
NONLIN_EOS
SPLIT_EOS
BULK_FLUX
BULK_EP
SPONGE
CLIMATOLOGY
ZCLIMATOLOGY
M2CLIMATOLOGY
M3CLIMATOLOGY
TCLIMATOLOGY
ZNUDGING
M2NUDGING
M3NUDGING
TNUDGING
ANA_BSFLUX
ANA_BTFLUX
UV_VIS2
MIX_GP_UV
TS_DIF2
MIX_GP_TS
CLIMAT_TS_MIXH
LMD_MIXING

LMD_SKPP
LMD_BKPP
LMD_RIMIX
LMD_CONVEC
OBC_M2FLATHER
OBC_M3ORLANSKI
OBC_TORLANSKI
M2FILTER_COSINE

Linux 2.6.9-42.0.3.ELsmp x86_64
NUMBER OF THREADS: 1 BLOCKING: 1 x 1.

Spherical grid detected.

hmin hmax grdmin grdmax Cu_min Cu_max
75.000000 4803.032721 .301836927E+05 .331215714E+05 0.12176008 0.91533005
volume=9.523986093261087500000E+14 open_cross=6.104836888312444686890E+09

Vertical S-coordinate System:

level S-coord Cs-curve at_hmin over_slope at_hmax

32	0.0000000	0.0000000	0.000	0.000	0.000
31	-0.0312500	-0.0009350	-0.373	-2.584	-4.794
30	-0.0625000	-0.0019030	-0.749	-5.247	-9.746
29	-0.0937500	-0.0029380	-1.128	-8.074	-15.019
28	-0.1250000	-0.0040767	-1.515	-11.152	-20.790
27	-0.1562500	-0.0053591	-1.911	-14.580	-27.249
26	-0.1875000	-0.0068304	-2.319	-18.466	-34.613
25	-0.2187500	-0.0085426	-2.743	-22.938	-43.132
24	-0.2500000	-0.0105560	-3.186	-28.141	-53.095
23	-0.2812500	-0.0129416	-3.654	-34.248	-64.842
22	-0.3125000	-0.0157835	-4.151	-41.463	-78.776
21	-0.3437500	-0.0191819	-4.684	-50.031	-95.377
20	-0.3750000	-0.0232566	-5.262	-60.241	-115.220
19	-0.4062500	-0.0281514	-5.892	-72.443	-138.993
18	-0.4375000	-0.0340388	-6.588	-87.056	-167.524
17	-0.4687500	-0.0411263	-7.361	-104.584	-201.807
16	-0.5000000	-0.0496640	-8.228	-125.635	-243.041
15	-0.5312500	-0.0599527	-9.209	-150.939	-292.668
14	-0.5625000	-0.0723554	-10.328	-181.377	-352.427
13	-0.5937500	-0.0873092	-11.613	-218.013	-424.414
12	-0.6250000	-0.1053416	-13.097	-262.126	-511.156
11	-0.6562500	-0.1270882	-14.823	-315.262	-615.700
10	-0.6875000	-0.1533158	-16.841	-379.282	-741.723
9	-0.7187500	-0.1849493	-19.209	-456.432	-893.656
8	-0.7500000	-0.2231040	-22.002	-549.423	-1076.845
7	-0.7812500	-0.2691252	-25.306	-661.522	-1297.738

```

6 -0.8125000 -0.3246355 -29.226 -796.670 -1564.114
5 -0.8437500 -0.3915923 -33.891 -959.622 -1885.352
4 -0.8750000 -0.4723564 -39.453 -1156.112 -2272.770
3 -0.9062500 -0.5697755 -46.098 -1393.057 -2740.015
2 -0.9375000 -0.6872846 -54.048 -1678.800 -3303.552
1 -0.9687500 -0.8290268 -63.574 -2023.407 -3983.240
0 -1.0000000 -1.0000000 -75.000 -2439.016 -4803.033

```

Time splitting: ndtfast = 60 nfast = 89

Maximum grid stiffness ratios: rx0 =0.2353349875 rx1 = 2.5672736953

GET_INITIAL – Processing data for time = 0.000 record = 1

GET_TCLIMA – Read climatology of tracer 1 for time = 345.0

GET_TCLIMA – Read climatology of tracer 1 for time = 15.00

GET_TCLIMA – Read climatology of tracer 2 for time = 345.0

GET_TCLIMA – Read climatology of tracer 2 for time = 15.00

GET_UCLIMA – Read momentum climatology for time = 345.0

GET_UCLIMA – Read momentum climatology for time = 15.00

GET_SSH - Read SSH climatology for time = 345.0

GET_SSH - Read SSH climatology for time = 15.00

GET_SMFLUX – Read surface momentum stresses for time = 345.0

GET_SMFLUX – Read surface momentum stresses for time = 15.00

GET_BULK – Read fields for bulk formula for time = 345.0

GET_BULK – Read fields for bulk formula for time = 15.00

DEF_HIS/AVG - Created new netCDF file 'ROMS_FILES/roms_his.nc'.

WRT_GRID – wrote grid data into file 'ROMS_FILES/roms_his.nc'.

WRT_HIS – wrote history fields into time record = 1 / 1

MAIN: started time-stepping.

```

STEP time[DAYS] KINETIC_ENRG POTEN_ENRG TOTAL_ENRG NET_VOLUME trd
0 0.00000 0.000000000E+00 2.1475858E+01 2.1475858E+01 9.5239861E+14 0
1 0.06250 1.306369099E-04 2.1476230E+01 2.1476361E+01 9.5239208E+14 0
...

```

1.1.7 Long simulations

In many studies, there is a need for long simulations: to reach the spin-up of the solution and/or to obtain statistical equilibriums. For regional models, 10 years appears to be a reasonable model simulation length. In this case, to prevent the generation of large output files, the strategy is to relaunch the model every simulated month. This is done by the UNIX csh script: run_roms.csh . Warning! the ROMS input file use for long simulations is roms.inter.in. It should be edited accordingly.

1. It gets the grid, the forcing, the initial and the boundary files.

2. It runs the model for 1 month.
3. It stores the output files in a specific form: roms_avg_Y4M3.nc (for the ROMS averaged output of March of year 4).
4. It replaces the initial file by the restart file (roms_rst.nc) which as been generated at the end of the month.
5. It relaunch the model for next month.

Part to edit in run_roms.csh:

```
set MODEL=roms
set SCRATCHDIR='pwd'/SCRATCH
set INPUTDIR='pwd'
set MSSDIR='pwd'/ROMS_FILES
set MSSOUT='pwd'/ROMS_FILES
set CODFILE=roms
set AGRIF_FILE=AGRIF_FixedGrids.in
#
# Model time step [seconds]
#
set DT=5400
#
# Number of days per month
#
set NDAYS = 30
#
# number total of grid levels
#
set NLEVEL=1
#
# Time Schedule - TIME_SCHED=0 -> yearly files
# TIME_SCHED=1 -> monthly files
#
set TIME_SCHED=1
#
set NY_START=1
set NY_END=10
set NM_START=1
set NM_END=12
```

Variables definitions:

- MODEL=roms : Name used for the input files. For example roms_grd.nc.
- SCRATCHDIR='pwd'/SCRATCH : Scratch directory where the model is run
- INPUTDIR='pwd' : Input directory where the roms_inter.in input file is.

- MSSDIR='pwd'/ROMS_FILES : Directory where the roms input NetCDF files (roms_grd.nc, roms_frc.nc, ...) are stored.
- MSSOUT='pwd'/ROMS_FILES : Directory where the roms output NetCDF files (roms_his.nc, roms_avg.nc, ...) are stored.
- CODFILE=roms : ROMS executable.
- AGRIF_FILE=AGRIF_FixedGrids.in : AGRIF input file which defines the position of child grids when using embedding.
- DT=5400 : Model time step in seconds.
- NDAYS = 30 : Number of days in 1 month.
- NLEVEL=1 : Total number of model grids (no AGRIF: NLEVEL=1).
- NY_START=1 : Starting year.
- NY_END=10 : Ending Year.
- NM_START=1 : Starting month.
- NM_END=12 : Ending month.

To run a ROMS long simulation in batch mode on a Linux workstation:

```
> : nohup ./run_roms.csh > exp1.out &
```

To check the execution of your model, type in the directory ~/Roms_Tools/Run :

```
>: more exp1.out
```

1.1.8 Getting the results

roms_gui

Once the model has run, or during the simulation, it is possible to visualize the model outputs using a Matlab graphic user interface : roms_gui. Launch roms_gui in the Matlab session (in the ~/Roms_tools/Run/ directory):

```
>>
>> roms_gui
```

A window pops up, asking for a ROMS history NetCDF file (Figure 1.4). You should select roms_his.nc (history file) or roms_avg.nc (average file) and click "open".

The main window appears, variables can be selected to obtain an image such as Figure (1.5). On the left side, the upper box gives the available ROMS variable names and the lower box presents the variables derived from the ROMS model outputs :

- Ke : Horizontal slice of kinetic energy: $0.5(u^2 + v^2)$.
- Rho : Horizontal slice of density using the non-linear equation of state for seawater of Jackett and McDougall (1995).

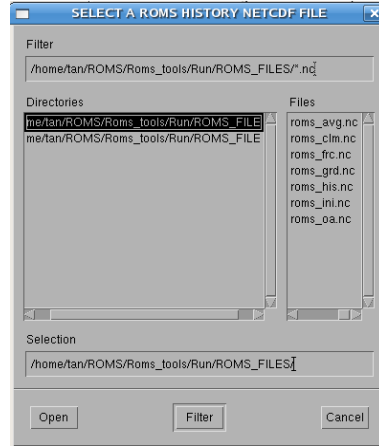


Figure 1.4: Entrance window of roms_gui

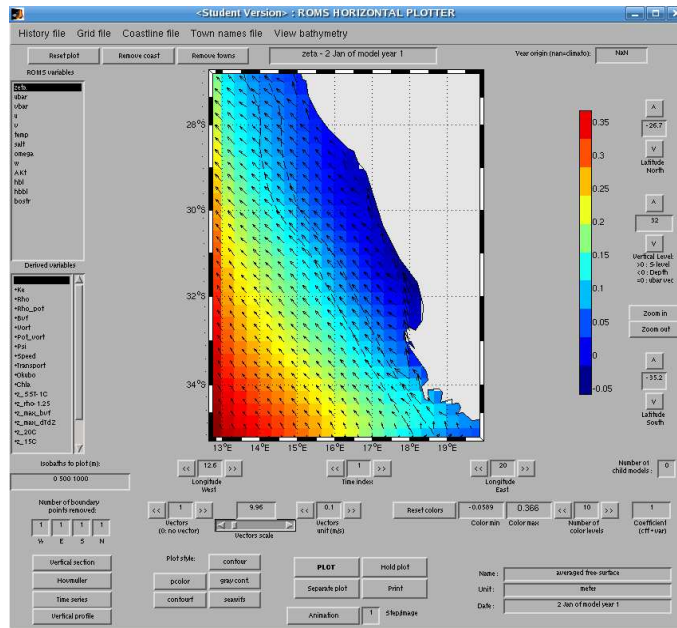


Figure 1.5: roms_gui

- Pot_Rho : Horizontal slice of the potential density.
- Bvf : Horizontal slice of the Brunt-Väisälä frequency: $N^2 = -\frac{g}{\rho} \frac{\partial \rho}{\partial z}$
- Vort : Horizontal slice of vorticity: $\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$.
- Pot_vort : Horizontal slice of the vertical component of Ertel's potential vorticity: $\frac{\partial \lambda}{\partial z} \left[f + \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} \right) \right]$. In our case, $\lambda = \rho$.
- Psi : Horizontal slice of stream function: $\nabla^2 \psi = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$. This routine might be costly since it inverts the Laplacian of the vorticity (using a successive over relaxation solver).
- Speed : Horizontal slice of the ocean currents velocity : $\sqrt{u^2 + v^2}$.

- Transport : Horizontal slice of the transport stream function : $\nabla^2 S_{vd} = \frac{\partial \bar{v}}{\partial x} - \frac{\partial \bar{u}}{\partial y}$.
- Okubo : Horizontal slice of the Okubo-Weiss parameter : $\Lambda^2 = \left(\frac{\partial u}{\partial x} - \frac{\partial v}{\partial y} \right)^2 + \left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y} \right)^2 - \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} \right)^2$.
- Chla : Compute a chlorophyll-a from Large and Small phytoplankton concentrations.
- z_SST_1C : Depth of 1°C below SST.
- z_rho_1.25 : Depth of 1.25 kg.m⁻³ below surface density.
- z_max_bvf : Depth of the maximum of the Brunt-Väisälä frequency.
- z_max_dtdz : Depth of the maximum vertical temperature gradient.
- z_20C : Depth of the 20°C isotherm.
- z_15C : Depth of the 15°C isotherm.
- z_sig27 : Depth of the 1027 kg.m⁻³ density layer.
- r_factor : $r = \frac{\nabla h}{2h} = \frac{h_{+1/2} - h_{-1/2}}{h_{+1/2} + h_{-1/2}}$

It is possible to add arrows for the horizontal currents by increasing the "Current vectors spatial step". It is also possible to obtain vertical sections, time series, vertical profiles and Hovmöller diagrams by clicking on the corresponding targets in roms_gui.

Diagnostics

To analyze the long simulations, a few scripts have been added in the directory:
~/Roms_tools/Diagnostic_tools:

- roms_diags.m : Get volume and surface averaged quantities from a ROMS simulation.
- plot_diags.m : Plot the averaged quantities computed by roms_diags.m.
- get_Mmean.m : Get the monthly mean climatology.
- get_Smean.m : Get the seasonal and annual mean climatology from the outputs of get_Mmean.m.
- get_Meddy.m : Get the monthly variance climatology (if the variable nonseasonal = 1, the non-seasonal variance is computed; i.e., the seasonal variation are filtered). It needs that get_Mmean.m and get_Smean.m are run before.
- get_Seddy.m : Get the seasonal and annual RMS from the results of get_Meddy.m.
- roms_anim.m : Create an animation from the monthly history or average files.

Run these scripts in a Matlab session. The obtained mean or eddy files can be visualized with roms_gui.

If you need to create and play ".fli" animations, you should install ppm2fli and xanim on your system. If you have a Linux PC, you can follow these steps:

1. log in as root
2. go to the directory where the file is saved.
3. type : rpm -Uvh ppm2fli-2.1-1.i386.rpm
4. type : rpm -Uvh xanim-2.80.1-12.i386.rpm
5. log out

If you are not using a Linux PC, you should ask your system administrator to install these programs.

1.2 Tides

Using the method described by Flather (1976), ROMS is able to propagate the different tidal constituents from its lateral boundaries. To do so, define the cpp keys TIDES, SSH_TIDES and UV_TIDES and recompile the model using jobcomp. To work correctly, the model should use the Flather (1976) open boundary radiation scheme (cpp key OBC_M2FLATHER defined).

The tidal components are added to the forcing file (XXX_frc.nc) by the Matlab program make_tides.m. Edit the file : ~/Roms_tools/Run/romstools_param.m. The part of the file that you should change is :

```
%%%%%%%%%%
%
% 5-Parameters for tidal forcing
%
%%%%%%%%%%
%
% TPXO file name (TPXO6 or TPXO7)
%
tidename=[ROMSTOOLS_dir,'TPXO6/TPXO6.nc'];
%
% Number of tides component to process
%
Ntides=10;
%
% Chose order from the rank in the TPXO file :
% "M2 S2 N2 K2 K1 O1 P1 Q1 Mf Mm"
% " 1 2 3 4 5 6 7 8 9 10"
%
tidalrank=[1 2 3 4 5 6 7 8 9 10];
%
% Compare with tidegauge observations
%
lon0=18.37;
lat0=-33.91; % Cape Town location
Z0=1; % Mean depth of the tidegauge in Cape Town
```

Variables definitions :

- `tidename=[ROMSTOOLS_dir,'TPXO6/TPXO6.nc']` : Location of the netcdf tidal dataset. This file is derived from the Oregon State University global model of ocean tides TPXO.6 (Egbert and Erofeeva, 2002). Data sources can be found at <http://www.oce.orst.edu/po/research/tide/global.html>. It is also possible to use TPXO7.
- `Ntides=10` : Number of tidal components to process. Warning! This value should be identical to the value of the parameter `Ntides` in `param.h`: "parameter (`Ntides=10`)".
- `tidalrank=[1 2 3 4 5 6 7 8 9 10]` : Order to select the different tidal components.
- `lon0=18.37;lat0=-33.91;Z0=1` : Location of a tidal gauge to compare the interpolated values with observations.

An important aspect is the definition of time and especially the choice of a time origin. This is defined in `~/Roms_tools/Run/romstools_param.m`:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
% 6-Temporal parameters (used for make_tides, make_NCEP, make_OGCM)
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
Yorig = 1900; % reference time for vector time
% in roms initial and forcing files
%
Ymin = 2000; % first forcing year
Ymax = 2000; % last forcing year
Mmin = 1; % first forcing month
Mmax = 3; % last forcing month
%
Dmin = 1; % Day of initialization
Hmin = 0; % Hour of initialization
Min_min = 0; % Minute of initialization
Smin = 0; % Second of initialization
%
SPIN_Long = 0; % SPIN-UP duration in Years
```

The origin of time (`Yorig`: 1 january of year `Yorig`) should be kept the same for all the preprocessing and postprocessing steps. Save `romstools_param.m` and run `make_tides` in the Matlab session:

```
>>
>> make_tides
```

You should obtain :

```
Start date for nodal correction : 1-Jan-2000
Reading ROMS grid parameters ...
Tidal components : M2 S2 N2 K2 K1 O1 P1 Q1 Mf Mm
Processing tide : 1 of 10
...
```

1.3 Inter-Annual simulations

ROMSTOOLS can help to realize inter-annual simulations. In this context, we rely on Ocean Global Circulations Models (OGCM) for the lateral boundary conditions and a global atmospheric reanalysis for the surface forcing (NCEP). To limit the volume of data which needs to be transfered over the Internet, we use Opendap to extract only the necessary subgrids.

1.3.1 Getting the surface forcing data from NCEP

The Matlab script `make_NCEP.m` is used to obtain the surface forcing data. It downloads the necessary NCEP surface forcing data (Sea Surface Temperature, Wind stress ...) over the Internet, and interpolates them on the model grid. Since `make_NCEP.m` works with the bulk parameterization (i.e. the `BULK_FLUX` and `BULK_EP` cpp keys should be defined in `cppdefs.h`), a surface forcing NetCDF file and a bulk NetCDF file are generated for each month of your simulation in the directory `~/Roms_tools/Run/ROMSFILES/`. The part of the file `romstools_param.m` that you should change is:

```
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
% 7 Parameters for Interannual forcing (SODA, ECCO, NCEP, ...)
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
% Path to Forcing data
%
FORC_DATA_DIR = [RUN_dir,'DATA/'];
%
Download_data = 1; % Get data from the OPENDAP sites
level = 0; % AGRIF level; 0=parent grid
%
% Options for make_NCEP
%
NCEP_dir= [FORC_DATA_DIR,'NCEP_',ROMS_config,'/']; % NCEP data directory
```

```

makefrfc = 1; % 1: Create forcing files
makeblk = 1; % 1: Create bulk files
add_tides = 0; % 1: Add the tides (To be done...)
%
NCEP_version = 1; % NCEP version:
% (1: NCEP/NCAR Reanalysis, 1/1/1948 - present
% 2: NCEP-DOE Reanalysis, 1/1/1979 - 12/31/2001)
%
```

Variables description :

- FORC_DATA_DIR : Directory where the different files downloaded over the Internet are stored.
- Download_data : Get data from the OPENDAP sites. Should be 1.
- level : AGRIF level. The parent grid = 0 and the child grid = 1.
- NCEP_dir= [FORC_DATA_DIR,'NCEP_',ROMS_config, '/'] : NCEP data directory. This is where NCEP data downloaded over the Internet are stored.
- makefrfc : Switch to define if the forcing file is generated. Should be 1.
- makeblk : Switch to define if the bulk file is generated. Should be 1.
- add_tides : Switch to define if the tidal forcing is added.
- NCEP_version : version of the NCEP reanalysis. 1: NCEP/NCAR Reanalysis, 1/1/1948 - present. 2: NCEP-DOE Reanalysis, 1/1/1979 - 12/31/2001.

Save romstools_param.m and run make_NCEP in the Matlab session. You should obtain:

```

>> make_NCEP
Add the paths of the different toolboxes
Arch : x86_64 - Matlab version : 2006a
Use of mexnc and loaddap in 64 bits.
Download NCEP data with OPENDAP
```

```

Get NCEP data from 2000 to 2000
Minimum Longitude: 12.3
Maximum Longitude: 20.3
Minimum Latitude: -35.5
Maximum Latitude: -26.3815
```

```

Making output data directory ../Run/DATA/NCEP_Benguela/
Process the first dataset: http://www.cdc.noaa.gov/cgi-bin/nph-nc/Datasets/ncep.reanalysis/surface-gauss/
Create ../Run/DATA/NCEP_Benguela/land.sfc.gauss.nc
Processing year: 2000
Processing month: 1
Get air for year 2000 - month 1
...
```


1.3.2 Getting the surface windstress data from QuickSCAT

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
% 7 Parameters for Interannual forcing (SODA, ECCO, NCEP, ...)
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
% Path to Forcing data
.....
% Options for make_QSCAT_daily and make_QSCAT_clim
%
QSCAT_dir = [FORC_DATA_DIR,'QSCAT_',ROMS_config, '/']; % QSCAT data directory.
QSCAT_frc_prefix = [frc_prefix,'_QSCAT_']; % generic forcing file name
% for interannual roms simulations with QuickSCAT.
QSCAT_clim_file = [DATADIR,'QuikSCAT_clim/',... % QuikSCAT climatology
'roms_QSCAT_month_clim_2000_2007.nc']; % file for make_QSCAT_clim.
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

If you want to use the QSCAT daily data, provided by the OpenDAP server at Ifremer, France: http://www.ifremer.fr/dodsG/CERSAT/quikscat_daily.

```
>> make_QSCAT_daily
```

if you download data over the internet using OpenDAP, you should obtain that during the dowload step :

```
>>
```

```
...
```

```
Reading: http://www.ifremer.fr/dodsG/CERSAT/quikscat_daily
```

```
Constraint: mwst[167:167][78:113][370:409]
```

```
Server version: apache-coyote/1.1
```

```
Processing day: 1
```

```
Reading: http://www.ifremer.fr/dodsG/CERSAT/quikscat_daily
```

```
Constraint: zwst[168:168][78:113][370:409]
```

```
Server version: apache-coyote/1.1
```

```
Reading: http://www.ifremer.fr/dodsG/CERSAT/quikscat_daily
```

```
Constraint: mwst[168:168][78:113][370:409]
```

```
Server version: apache-coyote/1.1
```

```
Processing day: 2
```

```
....
```

```
>>
```

If you want to use the QSCAT climatology, computed over 2000-2007, based over these previous QSCAT data :

```
>> make_QSCAT_clim
>> ...
```

1.3.3 Getting the lateral boundary conditions

Initial conditions and lateral boundary conditions can be obtained from several ocean global circulation models (OGCM) such as SODA (Carton et al., 2005) or ECCO (Stammer et al., 1999). The SODA reanalysis is available from 1958 to 2001 and ECCO is available from 1993 until now. The Matlab script make_OGCM.m is used to download data over the Internet, and to perform the interpolations on the model grid. A lateral boundary conditions NetCDF file is generated for each month of your simulation in the directory `~/Roms.tools/Run/ROMSFILES/`.

The part of the file `romstools_param.m` that you should change is:

```
%%%%%%%%%%%%%%
%
% Options for make_OGCM
%
%%%%%%%%%%%%%%
OGCM = 'SODA'; % Select the OGCM: SODA(1958-2001), ECCO(1993-2005), ...
OGCM_dir = [FORC_DATA_DIR,OGCM,'_',ROMS_config,'/'];
bry_prefix = [ROMS_files_dir,'roms_bry_',OGCM,'_'];
clm_prefix = [ROMS_files_dir,'roms_clm_',OGCM,'_'];
ini_prefix = [ROMS_files_dir,'roms_ini_',OGCM,'_'];
OGCM_prefix = [OGCM,'_'];
rmdepth = 2;
%
%
```

Variables description :

- `OGCM = 'SODA'` : Name of the OGCM employed (SODA or ECCO).
- `OGCM_dir = [FORC_DATA_DIR,OGCM,'_',ROMS_config,'/']` : OGCM data directory.
- `bry_prefix = [ROMS_files_dir,'roms_bry_',OGCM,'_']` : Left part of the boundary file name.
- `clm_prefix = [ROMS_files_dir,'roms_clm_',OGCM,'_']` : Left part of the climatology file name.
- `ini_prefix = [ROMS_files_dir,'roms_ini_',OGCM,'_']` : Left part of the initial file name.
- `OGCM_prefix = [OGCM,'_']` : Left part of the OGCM file name. This is where OGCM data are stored.

- `rmdepth = 2` : Number of bottom levels to remove. This is useful when there is no valid data at this level. For example, if the depth in the ROMS domain is shallower than the OGCM depth.

Save `romstools_param.m` and run `make_OGCM` in the Matlab session. You should obtain:

```
>> make_OGCM
```

```
Add the paths of the different toolboxes
```

```
Arch : x86_64 - Matlab version : 2006a
```

```
Use of mexnc and loaddap in 64 bits.
```

```
Download data...
```

```
Get data from Y2000M1 to Y2000M3
```

```
Minimum Longitude: 12.3
```

```
Maximum Longitude: 20.3
```

```
Minimum Latitude: -35.5
```

```
Maximum Latitude: -26.3815
```

```
Making output data directory ../Run/DATA/SODA_Benguela/
```

```
Process the dataset: http://iridl.ldeo.columbia.edu./SOURCES/.CARTON-GIESE/.SODA/.v1p4p3
```

```
Processing year: 2000
```

```
Processing month: 1
```

```
Download SODA for 2000 - 1
```

```
...SSH
```

```
...U
```

```
...
```

1.3.4 Running the model for interannual runs

Compile the model with `jobcomp` (and with the `cpp` keys `BULK_FLUX` and `BULK_EP` defined) and edit the input parameter file `~/Roms_tools/Run/roms_inter.in` as for the climatology experiments. As for the long simulations, a `csh` script (`run_roms_inter.csh`) manages the handling of input and output files. It also changes the number of time steps so each month has the correct length. This script takes care of leap years. For example `Y1996M2` (February 1996) is 29 days long.

Part to edit in `run_roms_inter.csh`:

```
#
set MODEL=roms
set SCRATCHDIR='pwd'/SCRATCH
set INPUTDIR='pwd'
set MSSDIR='pwd'/ROMS_FILES
set MSSOUT='pwd'/ROMS_FILES
set CODFILE=roms
set AGRIF_FILE=AGRIF_FixedGrids.in
#
set BULK_FILES=1
set FORCING_FILES=1
set CLIMATOLOGY_FILES=0
```

```

set BOUNDARY_FILES=1
#
# Atmospheric surface forcing dataset (NCEP, GFS,...)
#
set ATMOS=NCEP
#
# Oceanic boundary and initial dataset (SODA, ECCO,...)
#
set OGCM=SODA
#
# Model time step [seconds]
#
set DT=5400
#
# number total of grid levels (1: No child grid)
#
set NLEVEL=1
#
set NY_START=2000
set NY_END=2000
set NM_START=1
set NM_END=3
#
# Restart file - RSTFLAG=0 -> No Restart
# RSTFLAG=1 -> Restart
#
set RSTFLAG=0
#
# Time Schedule - TIME_SCHED=0 -> yearly files
# TIME_SCHED=1 -> monthly files
#
set TIME_SCHED=1
#
#####

```

Variables definitions:

- MODEL=roms : Name used for the input files. For example roms_grd.nc.
- SCRATCHDIR='pwd'/SCRATCH : Scratch directory where the model is run.
- INPUTDIR='pwd' : Input directory where the roms_inter.in input file is located.
- MSSDIR='pwd'/ROMS_FILES : Directory where the roms input NetCDF files (roms_grd.nc, roms_frc.nc, ...) are stored.
- MSSOUT='pwd'/ROMS_FILES : Directory where the roms output NetCDF files (roms_his.nc, roms_avg.nc, ...) are stored.
- CODFILE=roms : ROMS executable.

- AGRIF_FILE=AGRIF_FixedGrids.in : AGRIF input file which defines the position of child grids when using embedding.
- BULK_FILES=1 : 1 if using bulk NetCDF files (should be 1 for NCEP).
- FORCING_FILES=1 : 1 if using forcing NetCDF files (should be 1 for NCEP).
- CLIMATOLOGY_FILES=0 : 1 if using XXX_clm.nc files. Using a climatology file for each month can take a lot of disc space. It is less costly to use boundary files (XXX_bry.nc).
- BOUNDARY_FILES=1 : 1 if using XXX_bry.nc files.
- ATMOS=NCEP : name of the atmospheric reanalysis. For the moment it is only NCEP.
- OGCM=SODA : name of the OGCM for the boundary conditions. SODA or ECCO.
- DT=5400 : Model time step in seconds.
- NDAYS = 30 : Number of days in 1 month.
- NLEVEL=1 : Total number of model grids (no embedding: NLEVEL=1).
- NY_START=2000 : Starting year.
- NY_END=2000 : Ending Year.
- NM_START=1 : Starting month.
- NM_END=3 : Ending month.
- RSTFLAG=0 : 1 if restarting a simulation
- TIME_SCHED=1 : (obsolete) 0 if using yearly files, 1 if using monthly files. Since make_NCEP and make_OGCM are creating only monthly files, it should be always 1.

As for ROMS long climatology experiments, inter-annual experiments can be run in batch mode:

```
>: nohup ./run_roms_inter.csh > exp1.out &
```

1.4 Embedding

1.4.1 Embedded (child) model preparation

To run an embedded model, the user must provide the grid, the surface forcing and the initial conditions. To name the different files, AGRIF employs a specific strategy: if the parent file names are of the form: XXX.nc, the first child names will be of the form: XXX.nc.1, the second: XXX.nc.2, etc... This convention is also applied for the "roms.in" input files.

A graphic user interface (NestGUI) facilitates the generation of the different NetCDF files. Launch nestgui in the Matlab session (in the `~/Roms_tools/Run/` directory):

```
>>
>> nestgui
```

A window pops up, asking for a "PARENT GRID" NetCDF file (Figure 1.6). In our Benguela test case, you should select `~/Roms_tools/Run/ROMSFILES/roms_grd.nc` (grid file) and click "open". The main window appears (Figure 1.7).

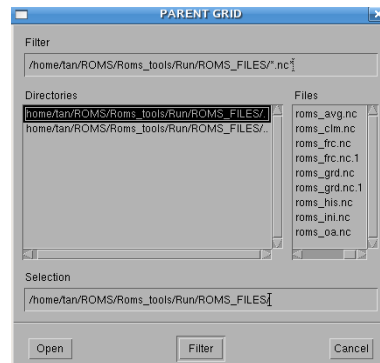


Figure 1.6: Entrance window of NestGUI

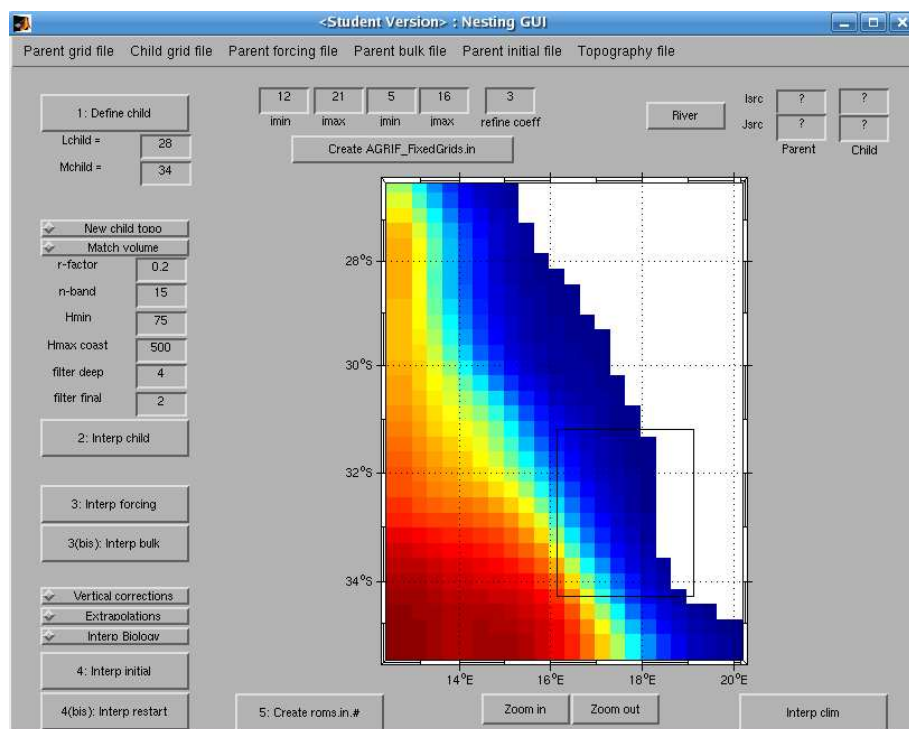


Figure 1.7: The NestGUI main window

To generate the child model you should follow several steps:

1. To define the child domain, click "Define child" and create the child domain on the

main window. The size of the grid child (Lchild and Mchild) is now visible. This operation can be redone until you are satisfied with the size and the position of the child domain. The child domain can be finely tuned using the imin, imax, jmin and jmax boxes. Be aware that the mask interpolation from the parent grid to the child grid is not optimal close to corners. Parent/Child boundaries should be placed where the mask is showing a straight coastline. A warning will be given during the interpolation procedure if this is not the case.

2. "Interp child" : It generates the child grid file. Before, you should select if you are using a new topography ("New child topo" button) for the child grid or if you are just interpolating the parent topography on the child grid. In the first case, you should define what topography file will be used (e.g. ~/Roms_tools/Topo/etopo2.nc or another dataset). You should also define if you want the volume of the child grid to match the volume of the parent close to the parent/child boundaries ("Match volume" button, it should be "on" by default). You should also define the r factor (Beckmann and Haidvogel, 1993) for topography smoothing ("r-factor", 0.25 is safe) and the number of points to connect the child topography to the parent topography ("n-band", it follows the relation $h_{new} = \alpha.h_{child} + (1 - \alpha).h_{parent}$, where α is going from 0 to 1 in "n-band" points from the parent/child boundaries). You should also select the child minimum depth ("Hmin", it should be lower or equal to the parent minimum depth), the maximum depth at the coast ("Hmax coast"), the number of selective hanning filter passes for the deep regions ("n filter deep") and the number of final hanning filter passes ("n filter final").
3. "Interp forcing": It interpolates the parent surface forcing on the child grid. Select the parent forcing file to be interpolated (e.g. ~/Roms_tools/Run/ROMSFILES/roms_frc.nc). The child forcing file roms_frc.nc.1 will be created. The parent surface fluxes are interpolated on the child grid. You can use "Interp bulk" if you are using a bulk formula. In this case, the parent bulk file (e.g. ~/Roms_tools/Run/ROMSFILES/roms_blk.nc) will be interpolated on the child grid.
4. "Interp initial": It interpolates parent initial conditions on the child grid. Select the parent initial file (e.g. ~/Roms_tools/Run/ROMSFILES/roms_ini.nc). The child initial file (e.g. ~/Roms_tools/Run/ROMSFILES/roms_ini.nc.1) will be created. If the topographies are different between the parent and the child grids, the child initial conditions are vertically re-interpolated. In this case you should check if the options "vertical corrections" and "extrapolations" are selected. "Interp biology" can be used to interpolate parent biological variables for biogeochemical experiments. "Interp restart" generates a child restart file from a parent restart file (e.g. ~/Roms_tools/Run/ROMSFILES/roms_rst.nc). This can be done to "hot start" a child model after the spin-up of the parent model.
5. You can click on "Create roms.in.*" to generate a child input file (roms.in.1) from the parent input file and click on "Create AGRIF_FixedGrids.in" to generate a AGRIF_FixedGrids.in file (the file which defines the child grid position in the parent grid).
6. "river" can be used to locate the river on the coast. "Interp clim" can be useful to generate boundary conditions to test the child model alone.

1.4.2 Compiling and running the model

The ROMS nesting procedure needs a Fortran 95 compiler. For Linux PCs, the Intel Fortran Compiler (ifort) is available at <http://www.intel.com/software/products/compilers/flin/noncom.htm>. To be able to compile ROMS with ifort, you should change the corresponding comments in jobcomp.

To activate the AGRIF nesting procedure, define AGRIF in `~/Roms_tools/Run/cppdefs.h`. Moreover, to activate the AGRIF nesting with the 2-way capability, define AGRIF and AGRIF_2WAYS.

It is possible to edit the file AGRIF_FixedGrids.in. This file contains the child grid positions (i.e. `imin,imax,jmin,jmax`) and coefficients of refinement. A first line gives the number of children grids per parent (if AGRIF_STORE_BAROT_CHILD is defined, only one child grid can be defined per parent grid). A second line gives the relative position of each grid and the coefficient of refinement for each dimension. Edit the input files `roms.in.1`, `roms.in.2`, etc... to define correctly the file names and the time steps. To run the model, simply type at the prompt: `roms roms.in`.

To visualize the ROMS model outputs for different grid levels, change the value in the "child models" box in `roms_gui`.

1.5 Biology

1.5.1 Idealized biogeochemical model : NChlPZD, N2ChlPZD2, N2P2Z2D2

ROMSTOOLS can help for the design of ROMS biogeochemical experiments. For the initial conditions and lateral boundary conditions, WOA provides a seasonal climatology for nitrateD concentration and WOA or SeaWifs can be used to obtain a seasonal climatology of surface chlorophyll concentration. Phytoplankton is estimated by a constant chlorophyll/phytoplankton ratio derived from previous simulations. Zooplankton is estimated in a similar way. The part which should be edited by the user in `romstools_param.m` is:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
% Open boundaries and initial conditions parameters
% used by make_clim.m, make_biol.m, make_bry.m
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
% World Ocean Atlas directory (WOA2001 or WOA2005)
%
woa_dir=[ROMSTOOLS_dir,'WOA2005/'];
%
% Surface chlorophyll seasonal climatology (WOA2001 or SeaWifs)
%
chla_dir=[ROMSTOOLS_dir,'SeaWifs/'];
%
```


Variables description :

- `woa_dir=[ROMSTOOLS_dir,'WOA2005/']` : Directory where the World Ocean Atlas 2005 climatology (Conkright et al., 2002) is located. The World Ocean Atlas 2001 climatology can also be used.
- `chla_dir=[ROMSTOOLS_dir,'SeaWifs/']` : Directory of the surface chlorophyll seasonal climatology.

Run `make_biol` in the Matlab session :

```
>>  
>> make_biol
```

You should obtain :

Add_no3: creating variables and attributes for the OA file
Add_no3: creating variables and attributes for the Climatology file

Ext tracers: Roa = 0 km - default value = NaN
Ext tracers: horizontal interpolation of the annual data
Ext tracers: horizontal interpolation of the seasonal data
time index: 1 of total: 4
time index: 2 of total: 4
time index: 3 of total: 4
time index: 4 of total: 4

Vertical interpolations

NO3...
Time index: 1 of total: 4
Time index: 2 of total: 4
Time index: 3 of total: 4
Time index: 4 of total: 4

CHla...
Add_chla: creating variable and attribute
...
Make a few plots...

The cpp keys related to these biology models are :

- `BIO_NChlPZD` : Select a 5 components (Nitrate, Chlorophyll, Phytoplankton, Zooplankton, Detritus) biogeochemical model.
- `BIO_N2ChlPZD2` : Select a 7 components (Nitrate, Ammonium, Chlorophyll, Phytoplankton, Zooplankton, Small Detritus, Large Detritus) biogeochemical model.
- `BIO_N2P2Z2D2` : Select a 8 components (Nitrate, Ammonium, Small Phytoplankton, Large Phytoplankton, Small Zooplankton, Large Zooplankton, Small Detritus,

Large Detritus) biogeochemical model.

- **DIAGNOSTICS_BIO** : Define if writing out fluxes between the biological components.

1.5.2 PISCES biogeochemical model

This latter is a more complex biogeochemical model, firstly coupled to OPA and now a beta version of the model can be coupled with ROMS_AGRIF. It is nicely described in (Aumont, 2005) provide in the documentation section of ROMS_TOOLS.

The cpp keys related to this biogeochemical model are :

- **PISCES** : Select the PISCES biogeochemical model
- **DIAGNOSTICS_BIO** : Define if writing out fluxes between the biological components.

ROMS_TOOLS provides preprocessing tools to design experiment using this biogeochemical model : `make_ini_piscs`, `make_clim_piscs`, `make_bry_piscs`, `make_bio_forcing.m` as for the climatological experiments.¹. This part of ROMS_TOOLS use the World Ocean Atlas, called WOAPISCES in ROMS_TOOLS, that provides the global data of Iron (Fe), Silicate (SiO₃), Oxygen (O₂), Phosphate (PO₄) dic (dissolved organic carbon), doc (dissolved inorganic carbon) and Alkanility.

In the `make_clim_piscs` :

```
%%%%%%%%%USERS DEFINED VARIABLES%%%%%%%%%
%
% Switches for selecting what to process (1=ON)
%
romstools_param
%
% Climatology files
%
DATADIR='../Data_Roms_Local/';
no3_seas_data = [DATADIR,'WOAPISCES/no3_seas.cdf'];
no3_ann_data = [DATADIR,'WOAPISCES/no3_ann.cdf'];
po4_seas_data = [DATADIR,'WOAPISCES/po4_seas.cdf'];
po4_ann_data = [DATADIR,'WOAPISCES/po4_ann.cdf'];
o2_seas_data = [DATADIR,'WOAPISCES/o2_seas.cdf'];
o2_ann_data = [DATADIR,'WOAPISCES/o2_ann.cdf'];
sio3_seas_data = [DATADIR,'WOAPISCES/sio3_seas.cdf'];
sio3_ann_data = [DATADIR,'WOAPISCES/sio3_ann.cdf'];
dic_seas_data = [DATADIR,'WOAPISCES/dic_seas.cdf'];
dic_ann_data = [DATADIR,'WOAPISCES/dic_ann.cdf'];
talk_seas_data = [DATADIR,'WOAPISCES/talk_seas.cdf'];
```

¹These routines use `add_dic.m`, `add_doc.m`, `add_fer.m`, `add_o2.m`, `add_talk.m`, `add_sio3.m`, `add_ini_dic.m`, `add_ini_doc.m`, `add_ini_fer.m`, `add_ini_o2.m`, `add_ini_talk.m`, `add_ini_po4.m`, `add_ini_sio3.m`

```

talk_ann_data = [DATADIR,'WOAPISCES/talk_ann.cdf'];
doc_seas_data = [DATADIR,'WOAPISCES/doc_seas.cdf'];
doc_ann_data = [DATADIR,'WOAPISCES/doc_ann.cdf'];
fer_seas_data = [DATADIR,'WOAPISCES/fer_seas.cdf'];
fer_ann_data = [DATADIR,'WOAPISCES/fer_ann.cdf'];
dust_seas_data = [DATADIR,'WOAPISCES/dust_seas.cdf'];
dust_ann_data = [DATADIR,'WOAPISCES/dust_ann.cdf'];
%
cycle=woa_cycle;
NO3min=1;

```

To add the boundary condition for the PISCES variables in xxx_clm.nc file :

```

>>
>> make_clim_pisces

```

```

Add_no3: creating variables and attributes for the OA file
write no3time
Add_po4: creating variables and attributes for the OA file
Add_sio3: creating variables and attributes for the OA file
Add_o2: creating variables and attributes for the OA file
Add_dic: creating variables and attributes for the OA file
Add_talk: creating variables and attributes for the OA file
Add_doc: creating variables and attributes for the OA file
Add_fer: creating variables and attributes for the OA file

```

```

Ext tracers: Roa = 0 km - default value = NaN
Ext tracers: horizontal interpolation of the seasonal data
time index: 1 of total: 12
time index: 2 of total: 12
time index: 3 of total: 12
time index: 4 of total: 12
time index: 5 of total: 12
time index: 6 of total: 12
time index: 7 of total: 12
time index: 8 of total: 12
time index: 9 of total: 12
time index: 10 of total: 12
time index: 11 of total: 12
time index: 12 of total: 12

```

To add initial condition for PISCES variables to xxx_ini.nc file :

```
>>
>> make_ini_pisces
```

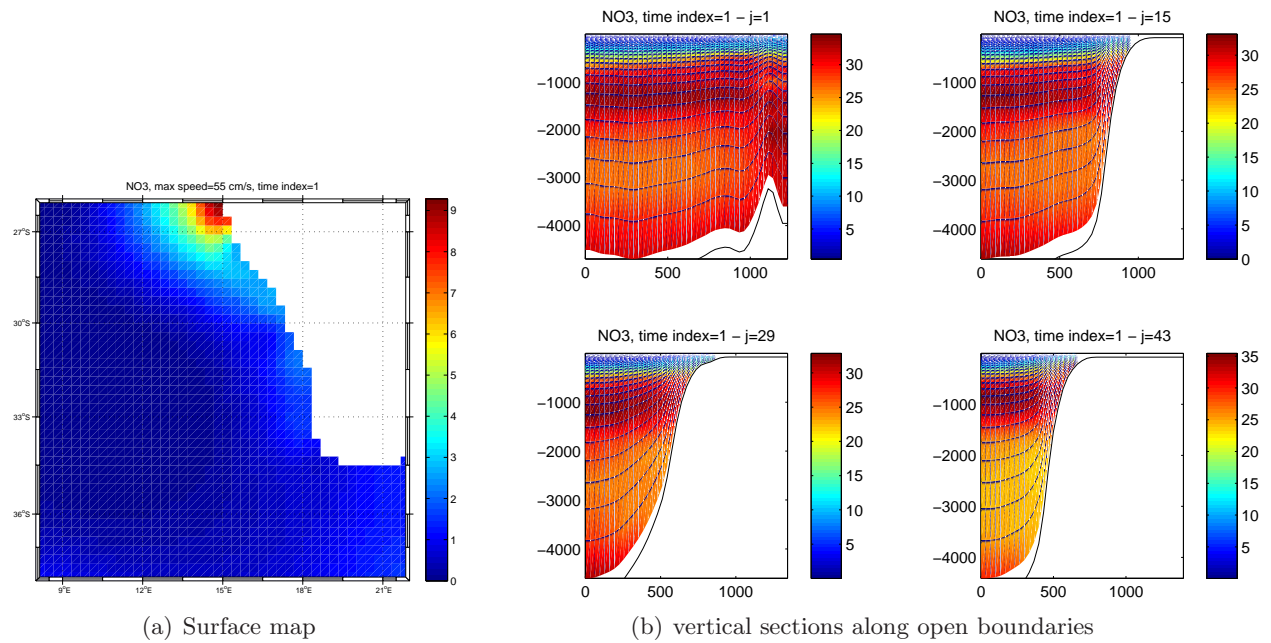


Figure 1.8: Result of make_clim_pisces for the Benguela example : NO3 forcing fields [mMol N m⁻³].

To compute the Iron dust deposition forcing file xxx_frcbio.nc file :

```
>>
>> make_dust
```

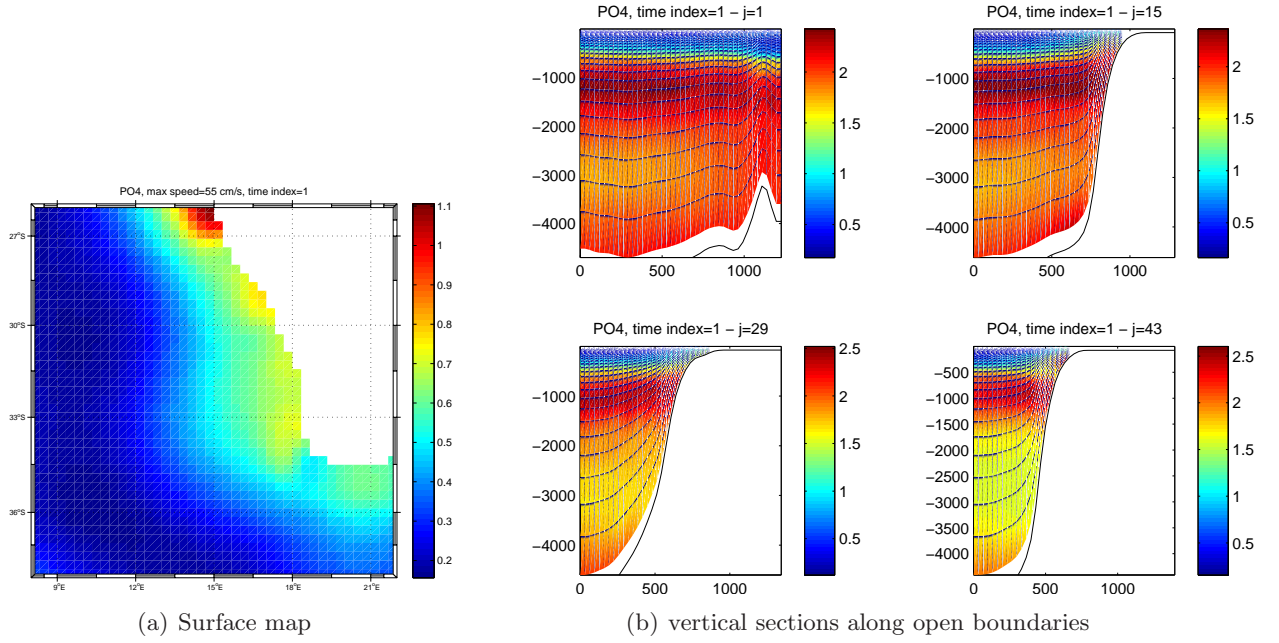


Figure 1.9: Result of `make_clim_pisces` for the Benguela example : PO4 forcing fields [mMol P m-3].

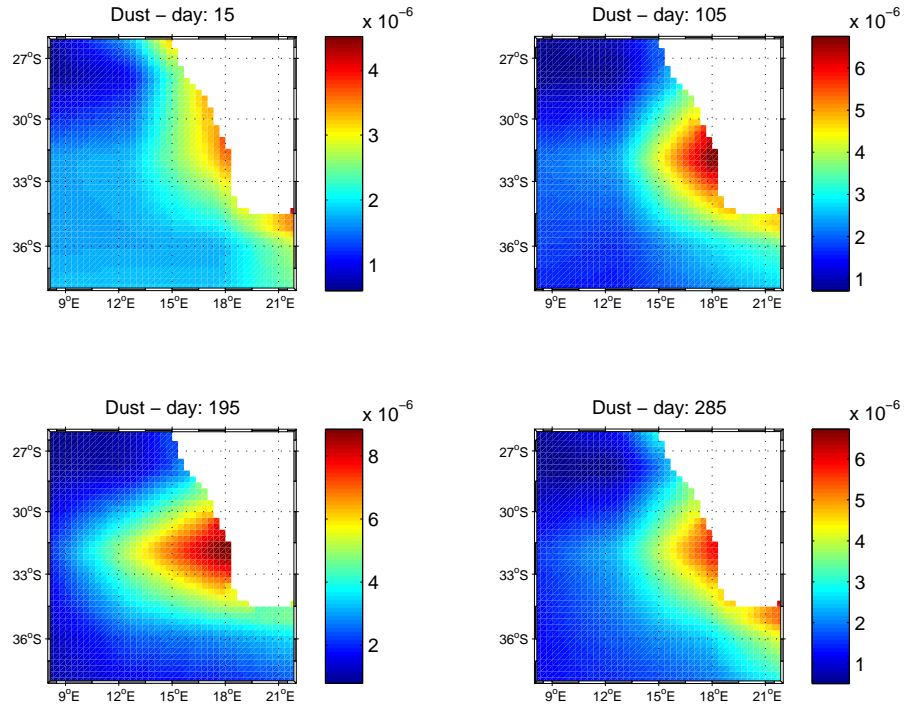


Figure 1.10: Result of `make_clim_pisces` for the Benguela example : Iron dust deposition forcing fields [nmol Fe m-3].

1.6 Operational coastal modeling system

An operating coastal modeling system can be designed following the assumption that large scale offshore dynamics are slow in comparison to the coastal system. The lateral boundary conditions are interpolated from the last available ECCO model outputs and are kept constant during the ROMS simulation. ECCO model outputs are delayed by about two to four weeks, but we suppose that they are still relevant for the present large scale oceanic structure. The Global Forecast System (GFS) is used for the surface forcing. A first day of simulation is run in hindcast mode. This will provide the initial conditions for the next simulated day. Using GFS as surface forcing and ECCO for the lateral boundary conditions, a forecast of 7 days is conducted. A UNIX C-Shell script (`/Roms_tools/Run/run_roms_forecast.csh`) manages data downloading, the hindcast and forecast simulations and data storage. The script `run_roms_forecast.csh` starts Matlab in batch mode to download with OPENDAP the lateral boundary conditions from ECCO and the surface forcing from GFS. It interpolates the data on ROMS grid and launches the hindcast and the forecast runs.

The script `run_roms_forecast.csh` should be edited to change the directory pathways (HOME, RUNDIR, PATH, LD_LIBRARY_PATH, MATLAB,...).

The ROMS input files `~/Roms_tools/Run/roms_hindcast.in` and `~/Roms_tools/Run/roms_forecast.in` should also be edited to change the length of the time step and the number of time steps. The ROMS input file `roms_hindcast.in` should be defined such as the hindcast run duration is 1 day and a restart file is generated at the end of the hindcast run.

The script `run_roms_forecast.csh` can be relaunched everyday in batch mode using `crontab`.

Chapter 2

ROMS_AGRIF 2.0

2.1 The ROMS model

ROMS solves the primitive equations in an Earth-centered rotating environment, based on the Boussinesq approximation and hydrostatic vertical momentum balance. ROMS is discretized in coastline- and terrain-following curvilinear coordinates. ROMS is a split-explicit, free-surface ocean model, where short time steps are used to advance the surface elevation and barotropic momentum, with a much larger time step used for temperature, salinity, and baroclinic momentum. ROMS employs a special 2-way time-averaging procedure for the barotropic mode, which satisfies the 3D continuity equation (Shchepetkin and McWilliams, 2005). The specially designed predictor-corrector time step algorithm used in ROMS allows a substantial increase in the permissible time-step size.

ROMS has been designed to be optimized on shared memory parallel computer architectures such as the SGI/CRAY Origin 2000. Parallelization is done by two dimensional sub-domains partitioning. Multiple sub-domains can be assigned to each processor in order to optimize the use of processor cache memory. This allow super-linear scaling when performance growth even faster than the number of CPUs.

The third-order, upstream-biased advection scheme implemented in ROMS allows the generation of steep gradients, enhancing the effective resolution of the solution for a given grid size (Shchepetkin and McWilliams, 1998). Explicit lateral viscosity is null everywhere in the model domain except in sponge layers near the open boundaries where it increases smoothly close to the lateral open boundaries.

A non-local, K-profile planetary (KPP) boundary layer scheme (Large, 1994) parameterizes the unresolved physical vertical subgrid-scale processes. If a lateral boundary faces the open ocean, an active, implicit, upstream biased, radiation condition connects the model solution to the surroundings (Marchesiello et al., 2001).

More informations and model description can be found in the SCRUM Manuel (Hedstroem, K. S. , 1997) that is available on the ROMS_AGRIF web site : <http://roms.mpl.ird.fr> in the documentation section.

2.2 Nesting capabilities, 1-WAYS and 2-WAYS using the AGRIF procedure

2.2.1 Introduction

To address the challenge of bridging the gap between near-shore and offshore dynamics, a nesting capability has been added to ROMS and tested for the California Upwelling System (Penven et al., 2006). The method chosen for embedded gridding takes advantage of the AGRIF (Adaptive Grid Refinement in Fortran) package (Blayo and Debreu, 1999; Debreu, 2000; Debreu and Blayo, 2003; Debreu and Vouland, 2003; Debreu and Blayo, 2008). AGRIF is a Fortran 95 package for the inclusion of adaptive mesh refinement features within a finite difference numerical model. One of the major advantages of AGRIF in static-grid embedding is the ability to manage an arbitrary number of fixed grids and an arbitrary number of embedding levels.

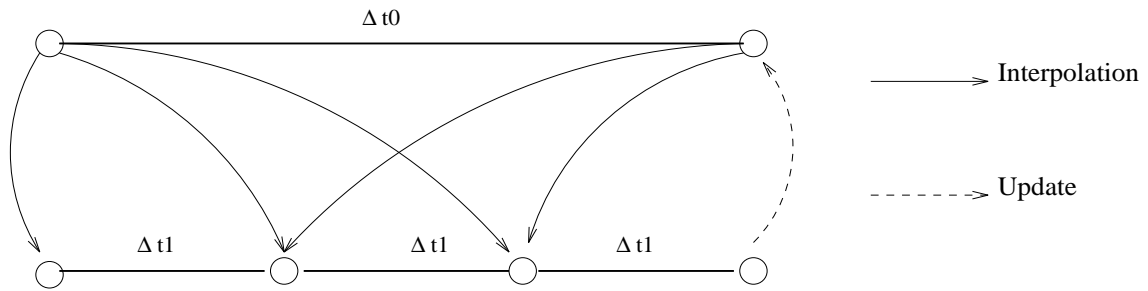


Figure 2.1: Temporal coupling between a parent and a child grid for a refinement factor of 3. The coupling is done at the baroclinic time step.

A recursive integration procedure manages the time evolution for the child grids during the time step of the parent grids (Figure 2.1). In order to preserve the CFL criterion, for a typical coefficient of refinement (say, a factor of 3 for a 5 km resolution grid embedded in a 15 km grid), for each parent time step the child must be advanced using a time step divided by the coefficient of refinement as many time as necessary to reach the time of the parent (Figure (2.1)). For simple 2-level embedding, the procedure is as follows:

1. Advance the parent grid by one parent time step.
2. Interpolate the relevant parent variables in space and time to get the boundary conditions for the child grid.
3. Advance the child grid by as much child time steps as necessary to reach the new parent model time.
4. Update point by point the parent model by averaging the more accurate values of the child model (in the case of 2-way embedding).

The recursive approach used in AGRIF allows the specification of any number of embedding level. Other cpp keys are related to AGRIF, they are in `set_global_definitions.h` and `set_obc_definitions.h` files. These ones are the default conditions, are located in the ROMS_AGRIF code sources and should not be edit by standard user.

2.2.2 2-WAYS nesting: feed-back from child to parent grid

To be continued ...

2.3 Changelog since ROMS_AGRIF 1.0

2.3.1 Numerical issues

Advection-Diffusion schemes

...reference a votre papier Patrick et Laurent

2D-3D coupling

...reference au nouveau stepping??

MPI parallelization

... effort de parrallelisation MPI

2.3.2 Nesting

... rfrence au 2-ways nesting et au futur papier :-) uswc 5-15

2.3.3 Online diagnostics and I/O

On parle ici de

- Nouvelles variables sorties
- Diagnostics TS MLD/ADV
- Nouvelles cles pour les bulk

2.3.4 PISCES biogeochemical model

... refrence au possibilites de simulation avec le modele PISCES

2.4 Parameters description : *parameter.h*

In this section, we present the more important parameters to configure your own roms_agrif 2.0 run. These parameters are :

- **Test case or realistic run:**

```
...
#if defined BASIN - - - - - > Test case
parameter (LLm0= 60, MMm0= 50, N= 10)
#elif defined REGIONAL - - - - - > Realistic run
#  elif defined BENGUELA_LR
    parameter (LLm0= 41, MMm0= 42, N= 32) ! < -- BENGUELA_LR
#  else
    parameter (LLm0=39, MMm0= 32, N= 20)
#  endif
...
LLm0 MMm0 N
```

- **Grid size:**

- LLm0: Dimension (ghost points included) in the ξ direction.
- MMm0: Dimension (ghost points included) in the η direction.
- N: Number of ρ -vertical points, in the vertical grid.

- **Parallelization:**

```
....
!
! Domain subdivision parameters:
! =====
! NPP Maximum allowed number of parallel threads;
! NSUB_X,NSUB_E Number of SHARED memory subdomains in XI- and
! ETA-directions;
! NNODES Total number of MPI processes (nodes);
! NP_XI,NP_ETA Number of MPI subdomains in XI- and ETA-directions;
!
```

AUTOTLING : cppkeys that enable to compute the optimum subdomains partition in terms of computation time. This is computed during the 100 first time step of the Run (implemented by Laurent Debreu).

- **Tides:**

```
...
#if defined SSH_TIDES —— defined UV_TIDES
    integer Ntides
    parameter (Ntides=8)— - - > Number of wave in the total tidal signal
#endif
...
```

2.5 CPP-keys description *cppdefs.h*

In this section, we present the different cpp keys used to define the numerical or physical options in ROMS_AGRIF. These latter are ordered in different sections and described in Table 2.1.

TYPE	CPP KEYS NAME
<u>TEST CASE</u>	BASIN CANYON_A CANYON_B GRAV_ADJ INNER SHELF OVERFLOW SEAMOUNT SHELF FRONT SOLITON UPWELLING INTERNAL VORTEX REGIONAL : realistic configuration
Basic options	
Configuration Name	BENGUELA
Parallelization	OPENMP MPI PARALLEL_FILES AUTOTILING
Embedding	AGRIF AGRIF_2WAY
Open Boundary Conditions	TIDES OBC_EAST OBC_WEST OBC_NORTH OBC_SOUTH
Tides	TIDES SSH_TIDES UV_TIDES TIDERAMP
Applications	BIOLOGY FLOATS STATIONS
<i>Next page</i> →	

TYPE	CPP KEYS NAME
	PASSIVE_TRACER SEDIMENT BBL
More advanced options	
Model dynamics	SOLVE3D UV_COR UV_ADV
Grid configuration	CURVGRID SPHERICAL MASKING
Input/Output and Diagnostics	AVERAGES AVERAGES_K DIAGNOSTICS_TS DIAGNOSTICS_TS_ADV DIAGNOSTICS_TS_MLD DIAGNOSTICS_UV
Equation of State	SALINITY NONLIN_EOS SPLIT_EOS
Surface Forcing	QCORRECTION SFLX_CORR DIURNAL_SRFLUX BULK_FLUX LW_ONLINE BULK_EP BULK_SMFLUX BULK_WVEC BULK_WSTR
Lateral Tracer Mixing	MIX_GP_TS MIX_S_TS MIX_EN_TS TS_DIF2 TS_DIF4 TS_SPLIT_UP3
Lateral Momentum Mixing	MIX_GP_UV MIX_S_GP UV_VIS2 UV_VIS4
<i>Next page</i> →	

TYPE	CPP KEYS NAME
Sponge Layer	UV_SPLIT_UP3
Lateral Forcing	SPONGE
<i>1-Climatology strategy : 3D fields covering the whole domain</i>	CLIMATOLOGY ZCLIMATOLOGY M2CLIMATOLOGY M3CLIMATOLOGY TCLIMATOLOGY
<i>2-Boundary strategy : 1D fields only on OBC points</i>	FRC_BRY Z_FRC_BRY M2_FRC_BRY M3_FRC_BRY T_FRC_BRY
Nudging	ZNUDGING M2NUDGING M3NUDGING TNUDGING ROBUST_DIAG
Bottom Forcing	ANA_BSFLUX ANA_BTFLUX
Point Sources - Rivers	PSOURCE ANA_PSOURCE
Vertical Mixing	BODYFORCE BVF_MIXING LMD_MIXING LMD_SKPP LMD_BKPP LMD_RIMIX LMD_CONVEC LMD_DDMIX LMD_NONLOCAL
Open Boundary Conditions	OBC_M2SPECIFIED OBC_M2FLATHER OBC_M2CHARACT
<i>Next page</i> →	

TYPE	CPP KEYS NAME
	OBC_M2ORLANSKI OBC_M2ORLANSKI OBC_VOLCONS OBC_M3ORLANSKI OBC_TORLANSKI OBC_M3SPECIFIED OBC_TSPECIFIED

Table 2.1: Description of the CPP keys used in the cppdefs.h file

Test Case

CPP KEYS NAME	Description
BASIN	Must be defined for running the Basin Example.
CANYON_A	Must be defined for running the Canyon_A Example.
CANYON_B	Must be defined for running the Canyon_B Example.
GRAV_ADJ	Must be defined for running the Gravitational Adjustment Example.
INNERSHELF	Must be defined for running the Inner Shelf Example.
OVERFLOW	Must be defined for running the Gravitational/Overflow Example.
SEAMOUNT	Must be defined for running the Seamount Example.
SHELFROUNT	Must be defined for running the Shelf Front Example.
SOLITON	Must be defined for running the Equatorial Rossby Wave Example.
UPWELLING	Must be defined for running the Upwelling Example.
INTERNAL	Must be defined for running the Internal tides example.
VORTEX	Must be defined for running the Baroclinic Vortex Example.
REGIONAL	Must be defined if running realistic regional simulations.

Table 2.2: Test Case related CPP keys

Parallelization

CPP KEYS NAME	Description
OPENMP	Activate the Open-MP parallelization protocol.
MPI	Activate the MPI parallelization protocol.
PARALLEL_FILES	Activate the I/O writing on multiprocessor.
AUTOTILING	Activate the subdomains partitionning optimization.

Table 2.3: Parallelization related CPP keys

Preselected options

```
# ifdef MPI
#   undef PARALLEL_FILES
# endif
# undef AUTOTILING
```

Embedding

CPP NAME	KEY	Description
AGRIF		Activate the (1-WAYS) nesting capabilities.
AGRIF_2WAYS		Add the the 2-WAYS nesting (feedback from child to parent grid) capabilities.

Table 2.4: Embedding related CPP keys

Open Boundary Conditions I

CPP NAME	KEY	Description
OBC_EAST		Open eastern boundary.
OBC_WEST		Open western boundary.
OBC_SOUTH		Open southern boundary.
OBC_NORTH		Open northern boundary.

Table 2.5: Open Boundary Conditions (basic) related CPP keys

Tides

CPP NAME	KEY	Description
TIDES		Activate the forcing og tides at open-boundaries.
SSH_TIDES		Define for processing sea surface elevation tidal data at the model boundaries.
UV_TIDES		Define for processing ocean current tidal data at the model boundaries.
TIDERAMP		Apply a ramping of the tidal current, (in general 2 days) at initialization. Warning! This should be off when restarting the model.

Table 2.6: Tides forcing related CPP keys

Preselected options

```
# ifdef TIDES
# define SSH_TIDES
# define UV_TIDES
# define TIDERAMP
# endif
```


Applications

CPP KEY NAME	Description
BIOLOGY	Activate the biogeochemical module.
FLOATS	Activate floats.
STATIONS	Store model outputs for each time step at different station locations.
PASSIVE_TRACER	Add a passive tracer.
SEDIMENT	Activate the sediment module.
BBL	Activate the bottom boundary layer module.

Table 2.7: related CPP keys

Preselected options:

```
# undef BIOLOGY
# undef FLOATS
# undef STATIONS
# undef PASSIVE_TRACER
# undef SEDIMENT
# undef BBL
```

Model dynamics

CPP KEY NAME	Description
SOLVE3D	Define if solving 3D primitive equations.
UV_COR	Activate Coriolis terms.
UV_ADV	Activate advection terms.

Table 2.8: Model dynamics related CPP keys

Preselected options:

```
# define SOLVE3D
# define UV_COR
# define UV_ADV
# ifdef TIDES
#   define SSH_TIDES
#   define UV_TIDES
#   define TIDERAMP
# endif
```

Grid configuration

CPP KEY NAME	Description
CURVGRID	Activate curvilinear coordinate grid option.
SPHERICAL	Activate longitude/latitude grid positioning.
MASKING	Activate land masking in the domain.

Table 2.9: Model grid related CPP keys

Preselected options:

```
# define CURVGRID
# define SPHERICAL
# define MASKING
```

Input - Output and Diagnostics

CPP KEY NAME	Description
AVERAGES	Define if writing out time-averaged data.
AVERAGES_K	Define if writing out time-averaged vertical mixing.
DIAGNOSTICS_TS	Define if writing out tendency terms for the tracer equations.
DIAGNOSTICS_TS_ADV	Activate advection formulation for tendency term for the tracer equations.
DIAGNOSTICS_TS_MLD	Activate integration over the mixed-layer (MLD) for the tendency term for the tracer equation.
DIAGNOSTICS_UV	Define if writing out tendency terms for the momentum equations.

Table 2.10: I/O related CPP keys

Preselected options:

```
# define AVERAGES
# define AVERAGES_K
# undef DIAGNOSTICS_TS
# ifdef DIAGNOSTICS_TS
#   undef DIAGNOSTICS_TS_ADV
#   undef DIAGNOSTICS_TS_MLD
# endif
# undef DIAGNOSTICS_UV
```

Equation of state

CPP KEY NAME	Description
SALINITY	Define if using salinity.
NONLIN_EOS	Activate the nonlinear equation of state.
SPLIT_EOS	Activate the split of the nonlinear equation of state in a adiabatic part and a compressible part for the reduction of pressure gradient errors (Shchepetkin and McWilliams, 2003).

Table 2.11: Equation of state related CPP keys

Preselected options:

```
# define SALINITY
# define NONLIN_EOS
# define SPLIT_EOS
```

Surface Forcing

CPP KEY NAME	Description
QCORRECTION	Activate net heat flux correction.
SFLX_CORR	Activate freshwater flux correction.
DIURNAL_SRFLUX	Activate diurnal modulation of the short wave radiation flux.
BULK_FLUX	Activate the bulk parametrization.
BULK_EP	Activate the bulk parametrization for salinity fluxes.
LW_ONLINE	Activate online long-wave radiation calculation using model sst.
BULK_SMFLUX	Activate the bulk parametrization for surface momentum stress and/or wind
BULK_WVEC	Compute the wind speed amplitude from the wind speed vector (uwnd and vwnd) read in the bulk file.
BULK_WSTR	Activate the bulk parametrization for wind stress calculation. Compute the windstress (sustr and svstr) from the wind speed vector, mentioned above.

Table 2.12: Surface forcing related CPP keys

Preselected options:

```
# define QCORRECTION
# define SFLX_CORR
# define DIURNAL_SRFLUX
# undef BULK_FLUX
# ifdef BULK_FLUX
#   define LW_ONLINE
#   define BULK_EP
#   undef BULK_SMFLUX
#   define DIURNAL_SRFLUX
# endif
```

```

# ifdef BULK_EP
#   undef QCORRECTION
#   undef SFLX_CORR
# endif
# ifdef BULK_SMFLUX
#   undef BULK_WVEC
#   define BULK_WSTR
# endif

```

Lateral Tracer mixing

CPP NAME	KEY	Description
MIX_GP_TS		Activate mixing on geopotential (constant Z) surfaces.
MIX_S_TS		Activate mixing on iso-sigma level surfaces.
MIX_EN_TS		Activate mixing on isopycnal level surfaces.
TS_DIF2		Activate Laplacian horizontal mixing of tracer.
TS_DIF4		Activate Bilaplacian horizontal mixing of tracer.
TS_SPLIT_UP3		Activate the rotated split upstream advection-diffusion scheme for tracer equation. (Marchesiello et al , 2009)

Table 2.13: Lateral Tracer mixing related CPP keys

Preselected options:

```

# define MIX_GP_TS
# define TS_DIF2
# undef TS_SPLIT_UP3

```

Lateral Momentum Mixing

CPP NAME	KEY	Description
MIX_GP_UV		Activate mixing on geopotential (constant Z) surfaces.
MIX_S_UV		Activate mixing on iso-sigma (constant sigma) surfaces.
UV_VIS2		Activate Laplacian horizontal mixing of momentum.
UV_VIS4		Activate Bilaplacian horizontal mixing of momentum.

Table 2.14: Lateral Momentum mixing related CPP keys

Preselected options:

```

# define UV_VIS2
# define MIX_GP_UV
# undef UV_SPLIT_UP3
# undef VIS_SMAGO

```

Sponge Layer

CPP NAME	KEY	Description
SPONGE		Activate areas of enhanced viscosity/diffusion close to the lateral open boundaries.

Table 2.15: Sponge layer related CPP keys

Lateral forcing

CPP NAME	KEY	Description
CLIMATOLOGY		Activate processing of climatology data.
ZCLIMATOLOGY		Activate processing of sea surface height climatology.
M2CLIMATOLOGY		Activate processing of barotropic velocities climatology.
M3CLIMATOLOGY		Activate processing of baroclinic velocities climatology.
TCLIMATOLOGY		Activate processing of tracer climatology.
FRC_BRY		Activate direct boundary forcing
Z_FRC_BRY		Activate boundary forcing for zeta.
M2_FRC_BRY		Activate boundary forcing for barotropic velocities.
M3_FRC_BRY		Activate boundary forcing for baroclinic velocities
T_FRC_BRY		Activate boundary forcing for tracers.

Table 2.16: Lateral forcing related CPP keys

Preselected options:

```
# define CLIMATOLOGY
# ifdef CLIMATOLOGY
#   define ZCLIMATOLOGY
#   define M2CLIMATOLOGY
#   define M3CLIMATOLOGY
#   define TCLIMATOLOGY
.....
```

```
# endif
```

```
# undef FRC_BRY
# ifdef FRC_BRY
#   define Z_FRC_BRY
#   define M2_FRC_BRY
#   define M3_FRC_BRY
#   define T_FRC_BRY
# endif
```

Nudging

CPP NAME	KEY	Description
ZNUDGING		Activate nudging layer for zeta.
M2NUDGING		Activate nudging layer for barotropic velocities.
M3NUDGING		Activate nudging layer for baroclinic velocities.
TNUDGING		Activate nudging layer for tracer.
ROBUST_DIAG		Activate strong tracer nudging in the interior for diagnostic simulations.

Table 2.17: Nudging related CPP keys

The nudging layer has the same location than sponge layer. In the sponge/nudging layer, the signal, tracers and momentum, is nudged towards climatology using a nudging coefficient τ_{out} expressed in $s-1$, equal to the inverse of the coefficient $TauM_{out}/TauT_{in}$ in the namelist roms.in

Preselected options:

```
# define CLIMATOLOGY
# ifdef CLIMATOLOGY
.....
#   define ZNUDGING
#   define M2NUDGING
#   define M3NUDGING
#   define TNUDGING
#   undef ROBUST_DIAG
# endif
```

Bottom forcing

CPP NAME	KEY	Description
ANA_BSFLUX		Define if using analytical bottom salinity flux
ANA_BTFLUX		Define if using analytical bottom temperature flux.

Table 2.18: Bottom forcing related CPP keys

Preselected options:

```
# define ANA_BSFLUX
# define ANA_BTFLUX
```

Point Sources - Rivers

CPP NAME	KEY	Description
PSOURCES		Define if using point sources (rivers)
ANA_PSOURCES		Define if using analytical vertical profiles for the point sources (using fluxes defined in roms.in)

Table 2.19: Point Sources and Rivers related CPP keys

Preselected options:

```
# undef PSOURCE
# undef ANA_PSOURCE
```

Vertical Mixing

CPP NAME	KEY	Description
BODYFORCE		Define if applying surface and bottom stresses as bodyforces
BVF_MIXING		Activate a simple mixing scheme based on the Brunt-Väisälä frequency
LMD_MIXING		Activate Large/McWilliams/Doney mixing (LMD-KPP closure)
LMD_SKPP		Activate surface boundary layer KPP mixing (LMD-KPP closure)
LMD_BKPP		Activate bottom boundary layer KPP mixing (LMD-KPP closure)
LMD_RIMIX		Activate shear instability interior mixing (LMD-KPP closure)
LMD_CONVEC		Activate convection interior mixing (LMD-KPP closure)
LMD_DDMIX		Activate double diffusion interior mixing (LMD-KPP closure)
LMD_NONLOCAL		Activate nonlocal transport (LMD-KPP closure)

Table 2.20: Vertical mixing related CPP keys

Preselected options:

```
# undef BODYFORCE
# undef BVF_MIXING
# define LMD_MIXING
# ifdef LMD_MIXING
#   define LMD_SKPP
#   define LMD_BKPP
#   define LMD_RIMIX
#   define LMD_CONVEC
#   undef LMD_DDMIX
#   undef LMD_NONLOCAL
# endif
```

Open Boundary Conditions II

CPP KEY NAME	Description
OBC_VOLCONS	Activate mass conservation enforcement at open boundaries.
OBC_M2SPECIFIED	Activate specified open boundary conditions for ubar and vbar.
OBC_M2ORLANSKI	Activate 2D radiation open boundary conditions for ubar and vbar.
OBC_M2FLATHER	Activate Flather open boundary conditions for ubar and vbar.
OBC_M2CHARACT	Activate open boundary conditions based on characteristic methods.
OBC_M3SPECIFIED	Activate specified open boundary conditions for u and v.
OBC_M3ORLANSKI	Activate 2D radiation open boundary conditions for u and v.
OBC_M3CHARACT	Activate open boundary conditions based on characteristic methods for u and v.
OBC_TSPECIFIED	Activate specified open boundary conditions for tracers.
OBC_TORLANSKI	Activate 2D radiation open boundary conditions for tracers.
OBC_TUPWIND	Activate upwind open boundary conditions for tracers.

Table 2.21: Open Boundary Condition related CPP keys

Preselected options:

```
# ifdef TIDES
#  define OBC_M2FLATHER
# else
#  undef OBC_M2SPECIFIED
#  undef OBC_M2FLATHER
#  define OBC_M2CHARACT
#  undef OBC_M2ORLANSKI
#  ifdef OBC_M2ORLANSKI
#   define OBC_VOLCONS
#  endif
# endif
# define OBC_M3ORLANSKI
# define OBC_TORLANSKI
# undef OBC_M3SPECIFIED
# undef OBC_TSPECIFIED
```


2.6 Namelist description : *roms.in*

2.6.1 Exemple of South Benguela Test Case

title:

South Benguela TEST MODEL

time_stepping: NTIMES dt[sec] NDTFAST NINFO

720 3600 60 1

S-coord: THETA_S, THETA_B, Hc (m)

7.0d0 0.0d0 5.0d0

grid: filename

roms_grd.nc

forcing: filename

roms_frc.nc

bulk_forcing: filename

roms_bulk.nc

climatology: filename

roms_clm.nc

boundary: filename

roms_bry.nc

initial: NRREC filename

1

roms_ini.nc

restart: NRST, NRPFRST / filename

720 -1

roms_rst.nc

history: LDEFHIS, NWRT, NRPFHIS / filename

T 72 0

roms_his.nc

averages: NTSAVG, NAVG, NRPF AVG / filename

1 72 0

roms_avg.nc

primary_history_fields: zeta UBAR VBAR U V wrtT(1:NT)

T T T T T 30*T

auxiliary_history_fields: rho Omega W Akv Akt Aks HBL HBBL Bostr Wstr UWstr

VWstr rsw rlw lat sen HEL

F F T F T F T T T T T T 10*F

primary_averages: zeta UBAR VBAR U V wrtT(1:NT)

T T T T T 30*T

auxiliary_averages: rho Omega W Akv Akt Aks HBL HBBL Bostr Wstr Wstr UWst

rsw rlw lat sen HEL

F T T F T F T T T T T T 10*F

rho0:

1025.d0

lateral_visc: VISC2, VISC4 [m^2 /sec for all]

0. 0.

tracer_diff2: TNU2(1:NT) [m^2 /sec for all]

30 * 0.d0

tracer_diff4: TNU4(1:NT) [m^4/sec for all]
 30 * 0.d11
vertical_mixing: Akv_bak, Akt_bak [m^2/sec]
 0.d0 30 * 0.d0
bottom_drag: RDRG [m/s], RDRG2, Zob [m], Cdb_min, Cdb_max
 3.0d-04 0.d-3 0.d-3 1.d-4 1.d-1
gamma2:
 1.d0
sponge: X_SPONGE [m], V_SPONGE [m^2 / sec]
 150.e3 100.
nudg_cof: TauT_in, TauT_out, TauM_in, TauM_out [days for all]
 1. 360. 3. 360.
diagnostics: ldefdia nwrt dia nprfdia /filename
 T 72 0
 roms_dia.nc
diag_avg: ldefdia_avg ntsdia_avg nwrt dia_avg nprfdia_avg /filename
 T 1 72 0
 roms_dia_avg.nc
diagnosticsM: ldefdiaM nwrt diaM nprfdiaM /filename
 T 72 0
 roms_diaM.nc
diagM_avg: ldefdiaM_avg ntsdiaM_avg nwrt diaM_avg nprfdiaM_avg /filename
 T 1 72 0
 roms_diaM_avg.nc
diagnostics_bio: ldefdiabio nwrt diabio nprfdiabio /filename
 T 72 0
 roms_diabio.nc
diagbio_avg: ldefdiabio_avg ntsdiabio_avg nwrt diabio_avg nprfdiabio_avg /filename
 T 1 72 0
 roms_diabio_avg.nc
biology: forcing file
 roms_frcbio.nc
sediments: input file
 sediment.in
sediment_history_fields: bed_thick bed_poros be3d_fra(sand,silt)
 T F T T
bbl_history_fields: Abed Hripple Lripple Zbnot Zbapp Bostrw
 T F F T F T
floats: LDEFFLT, NFLT, NRPFFLT / inpname, hisname
 T 6 0
 floats.in
 floats.nc
float_fields: Grdvar Temp Salt Rho Vel
 F F F F F
stations: LDEFSTA, NSTA, NRPFSTA / inpname, hisname
 T 400 0
 stations.in
 stations.nc

station_fields: Grdvar Temp Salt Rho Vel
 T T T T T
psource: Nsrc Isrc Jsrc Dsrc Qbar [m3/s] Lsrc Tsrc
 2
 3 54 1 200. T T 5.0.
 3 40 0 200. T T 5.0.

2.6.2 Description

KEYWORDS	DESCRIPTIONS
title	
time_stepping	NTIMES : Number of time step for the run. dt : Baroclinic time step for the run [in s] NDTFAST : Number of bariotropic time step in one baroclinic time step. NINFO : frequency of output in time steps.
S-coord	THETA_S: <i>s</i> -coordinate surface control parameter, $0 < \mathbf{theta_s} < 20$ THETA_B: <i>s</i> -coordinate bottom control parameter, $0 < \mathbf{theta_b} < 1$ Hc(m): Width of the surface or bottom topography layer in which higher vertical resolution is required during stretching.
grid	/filename: Name of the grid file.
forcing	/filename: Name of the surface forcing file : wind stress, atmospheric fluxes (E-P, net heat fluxes) and nudging coefficients towards dQ/dSST.
bulk_forcing	/filename: Name of the bulk forcing file for atmospheric forcings.
climatology	/filename: Name of the open boundaries conditions (<i>t</i> , <i>s</i> , \bar{u} , \bar{v} , <i>u</i> , <i>v</i>). These files are 3d in space, covering the whole domain.
boundary	/filename: Name of the open boundaries conditions (<i>T</i> , <i>S</i> , \bar{u} , \bar{v} , <i>u</i> , <i>v</i>). These files are covering only the open-boundaries slices, inducing files much smaller than the “climatology” ones.
initial	
<i>Next page</i> →	

KEYWORDS	DESCRIPTIONS
restart	NRREC: Record number of the restartfile to read as the initial conditions. /filename: Name of the file containing initial state.
history	NRST: Frequency of writing NRPFRST 0: writing several records every NRST time steps. -1: overwriting record every NRST time steps /filename
averages	LDEFHIS: flag (T/F) if writing history files NWRT: Frequency of writing NRPFHIS: 0: writing several records every NWRT time steps. -1: overwriting record every NRST time steps /filename: Name of the gistory file
primary_history_fields	NTSAVG: Starting timestep for the accumulation of output time-averaged data. For instance, you might want to average over the last day of a thirty-day run. NAVG: frequency of writing NRPEAVG: 0: writing several records every NWRT time steps. -1: overwriting record every NAVG time steps /filename
auxiliary_history_fields	Flags of written variables
primary_averages	Flags of written variables
auxiliary_averages	Flags of written variables
rho0	Mean density used in the Boussinesq equation.
lateral_visc	VISC2: Laplaplacian background viscosity VISC4: Bilaplacian background viscosity
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KEYWORDS	DESCRIPTIONS
tracer_diff2	TNU2(1:NT): Laplacian background diffusivity for each tracer.
tracer_diff4	TNU4(1:NT): Laplacian background diffusivity for each tracer.
vertical_mixing	Coefficient in case of use of analytical vertical mixing scheme.
bottom_drag	<p>RDRG [m/s]: Drag coefficient in case of linear bottom stress formulation.</p> <p>RDRG2: Drag coefficient in case of constant quadratic bottom stress formulation.</p> <p>Zob [m]: Rugosity length in case of Von-Karman quadratic bottom stress formulation</p> <p>Cdb_min: Minimum value of the drag coefficient in case Von-Karman quadratic bottom stress formulation.</p> <p>Cdb_max: Maximum value of the drag coefficient in case Von-Karman quadratic bottom stress formulation.</p>
gamma2	Free slip boundary condition. 1 mean free slip condition are ON.
sponge	<p>X_SPONGE [m]: widthness of the sponge layers.</p> <p>V_SPONGE [m^2/sec]: Value of the viscosity and diffusity enhanced value at the boundary point in the nudging/sponge layer. These value are enhanced following a linear profil in the sponge/nudging layer, from the interior value to the max value V_SPONGE at boundary.</p>
nudg_cof	<p>TauT_in [days]: Nudging time scale for tracer signal going inward the domain. This coefficient is used at boundary point and impose a strong nudging towards climatology external data.</p> <p>TauT_out [days]: Nudging time scale for tracer signal going outward the domain. This coefficient is used at boundary point and impose a smooth nudging towards climatology external data. This coefficient is also used in the nudging/sponge layer to add a smooth nudging towards data. This is on only if the CLIMATOLOGY boundary strategy is used, not the BRY one.</p>
<i>Next page</i> →	

KEYWORDS	DESCRIPTIONS
diagnostics	<p>TauM_in [days]: Same as above, but concerning the momentum equations.</p> <p>TauM_out [days]: Same as above, but concerning the momentum equations.</p> <p>ldefdia: Boolean flag to activate the tracer equation "snap-shot" diagnostic file writing</p> <p>nwrtdia: Frequency of writing</p> <p>nrpfdia: nrpfdia: 0: writing several records every nwrtdia time steps. -1: overwriting record every nwrtdia time steps</p> <p>/filename: Name of the file tracer equation diagnostic file.</p>
diag_avg	<p>ldefdia_avg: Boolean flag to activate the tracer equation average diagnostic file writing</p> <p>ntsdia_avg: Starting timestep for the accumulation of output time-averaged data. For instance, you might want to average over the last day of a thirty-day run.</p> <p>nwrtdia_avg: Frequency of writing and average time.</p> <p>nprfdia_avg: nrpfdia_avg: 0: writing several records every nwrtdia_avg time steps. -1: overwriting record every nwrtdia_avg time steps</p> <p>/filename: Name of the file tracer equation average diagnostic file.</p>
diagnosticsM	<p>Same format as diagnostics but for the momentum equation.</p> <p>ldefdiaM:</p> <p>nwrtdiaM:</p> <p>nrpfdiaM:</p> <p>/filename:</p>
diagM_avg	<p>Same format as diag_avg but for the momentum equation.</p> <p>ldefdiaM_avg:</p> <p>ntsdiaM_avg:</p> <p>nwrtdiaM_avg:</p> <p>nprfdiaM_avg:</p> <p>/filename</p>
diagnostics_bio	<p>Same format as diagnostics</p> <p>ldefdiabio</p> <p>nwrtdiabio</p> <p>nrpfdiabio</p> <p>/ filename</p>
diagbio_avg	<p>Same format as diag_avg</p> <p>ldefdiabio_avg</p>
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KEYWORDS	DESCRIPTIONS
biology	ntsdiabio_avg nwrt diabio_avg nprfdiabio_avg / filename Name of the file containing the Iron dust forcing if using PISCES biogeochemical mode.
sediments	
sediment_history_fields	bed_thick bed_poros bed_fra(sand,silt)
bbl_history_fields	Abed Hripple Lripple Zbnot Zbapp Bostrw
floats	Lagrangian floats application Same format as diagnostics LDEFFLT NFLT NRPFFLT / inpname, hisname
floats_fields	Type of fields computed for each lagrangian floats.
station_fields	Fixed station application. Same format as diagnostics LDEFSTA NSTA NRPFSTA / inpname, hisname
psource	Nsrc Isrc Jsrc
<i>Next page</i> →	

KEYWORDS	DESCRIPTIONS
	Dsrc Qbar [m ³ /s] Lsrc Tsrc

Table 2.22: Description of the roms.in file

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