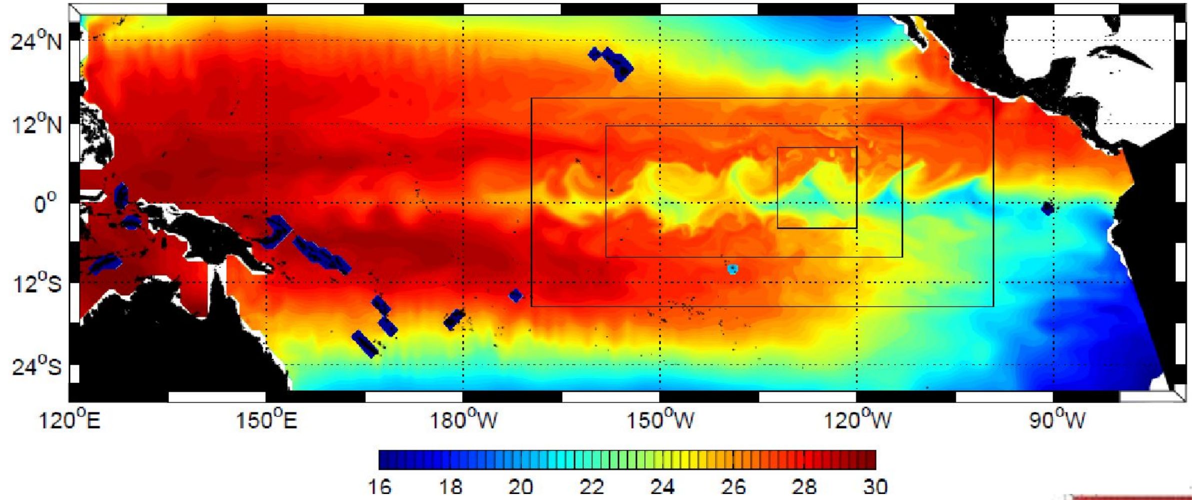
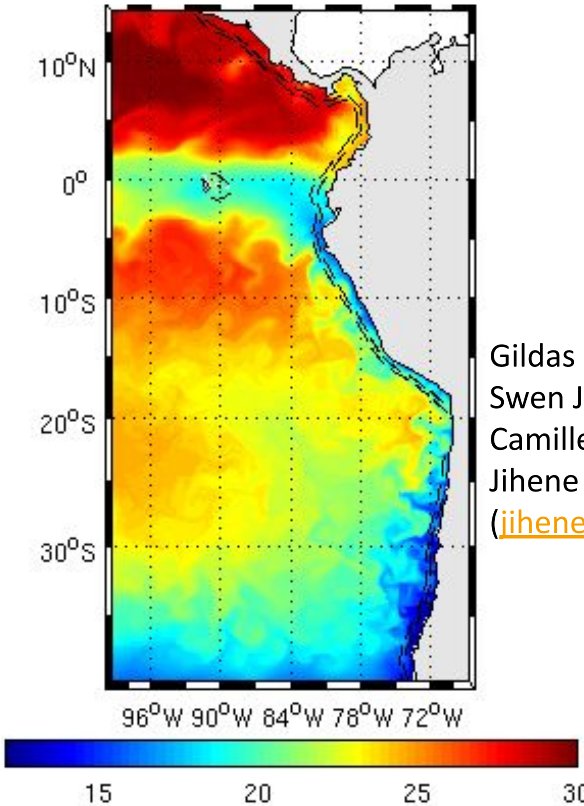
Introduction to CROCO / CROCO_TOOLS ocean modeling system



CROCO
Coastal and Regional Ocean COmmunity model



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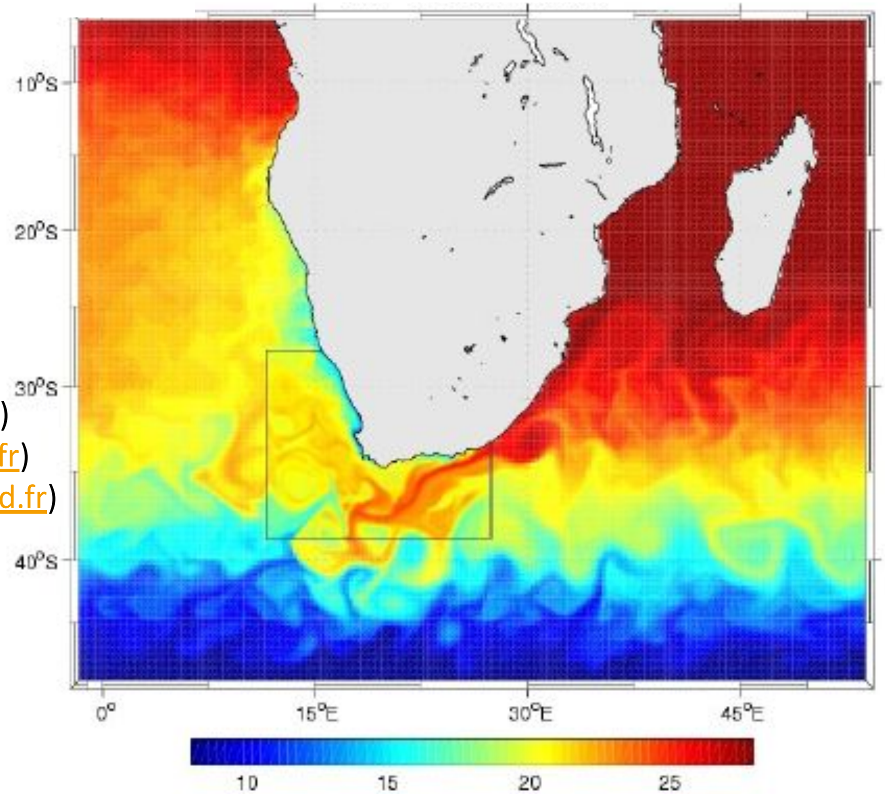


Introduction to CROCO / CROCO_TOOLS ocean modeling system

Coastal and Regional Ocean COmmunity model

1) Crocotools presentation for preprocessing

2) Climatology simulation (simulation one shot)

3) Inter annual simulation

Strategy to build a configuration

Global datasets

- GEBCO 1', Etopo2, SRTM30, ….
- COADS, QuikSCAT, CFSR, …
- WOA_2009, SODA, ECCO, Mercator, …

CROCOTOOLS

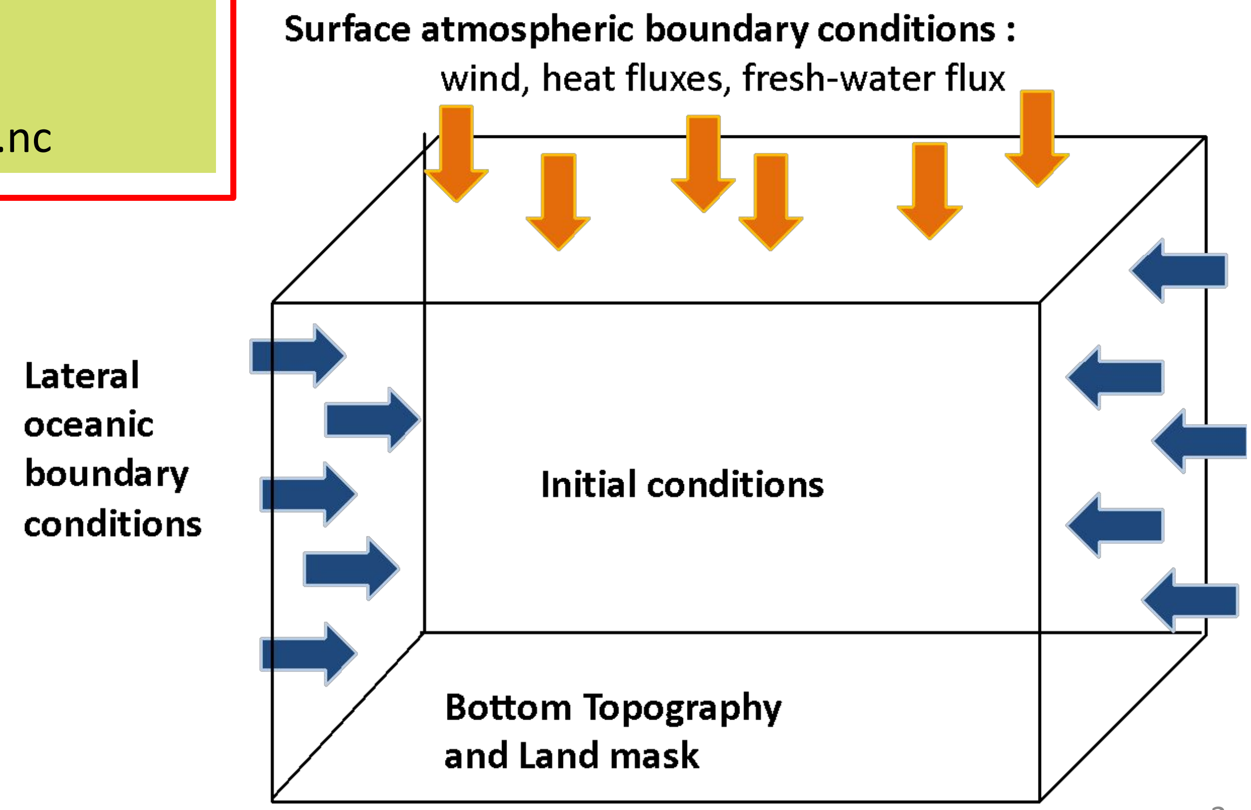
CROCO input netcdf files

- croco_grd.nc,
- croco_frc.nc, croco_blk.nc
- croco_ini.nc, croco_clm.nc, croco_bry.nc

I Pre-processing phase :

Input file creation :

- Topography
- Lateral oceanic boundaries
- Surface atmospheric boundaries



Strategy to build a configuration

Global datasets

- GEBCO 1’, Etopo2, SRTM30, ….
- COADS, QuikSCAT, CFSR, …
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CROCOTOOLS

CROCO input netcdf files

- croco_grd.nc,
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- croco_ini.nc, croco_clm.nc, croco_bry.nc

CROCO

I Pre-processing phase :

Input file creation :

- Topography
- Lateral oceanic boundaries
- Surface atmospheric boundaries

II Compilation phase :

- Create the croco executable with your options : numeric, physic and domain size

Strategy to build a configuration

Global datasets

- GEBCO 1', Etopo2, SRTM30, ….
- COADS, QuikSCAT, CFSR, …
- WOA_2009, SODA, ECCO, Mercator, …

CROCOTOOLS

CROCO input netcdf files

- croco_grd.nc,
- croco_frc.nc, croco_blk.nc
- croco_ini.nc, croco_clm.nc, croco_bry.nc

CROCO

CROCO output netcdf files

- croco_his.nc, croco_avg.nc
- croco_diags.nc, croco_diags_avg.nc
- croco_diagsM.nc, croco_diagsM_nc

…

I Pre-processing phase :

Input file creation :

- Topography
- Lateral oceanic boundaries
- Surface atmospheric boundaries

II Compilation phase :

- Create the croco executable with you options : numeric, physic and domain size

III Computing phase :

- the croco model run, resolve the primitive equation
- produce the outputs in croco_avg.nc, croco_his.nc

Strategy to build a configuration

Global datasets

- GEBCO 1', Etopo2, SRTM30, ….
- COADS, QuikSCAT, CFSR, …
- WOA_2009, SODA, ECCO, Mercator, …

CROCOTOOLS

CROCO input netcdf files

- croco_grd.nc,
- croco_frc.nc, croco_blk.nc
- croco_ini.nc, croco_clm.nc, croco_bry.nc

CROCO

CROCO output netcdf files

- croco_his.nc, croco_avg.nc
- croco_diags.nc, croco_diags_avg.nc
- croco_diagsM.nc, croco_diagsM_nc

…

CROCOTOOLS → analysis, visualization

I Pre-processing phase :

Input file creation :

- Topography
- Lateral oceanic boundaries
- Surface atmospheric boundaries

II Compilation phase :

- Create the croco executable with you options : numeric, physic and domain size

III Computing phase :

- the croco model run, resolve the primitive equation
- produce the outputs in croco_avg.nc, croco_his.nc

IV - Post processing / Analyse phase :

- Visualize and analyze model results …

System requirement

OS: LINUX or UNIX
CROCO : fortran program ~ (55000 lines of FORTRAN code)
CROCOTOOLS : Matlab (Octave) scripts + datasets (18 Gb)

PC configuration:

- Fortran Compiler : gfortran, Intel Fortran Compiler
- NetCDF : http://www.unidata.ucar.edu
- OpenMPI : http://www.open-mpi.org
- Matlab (or Octave)

Library needed :

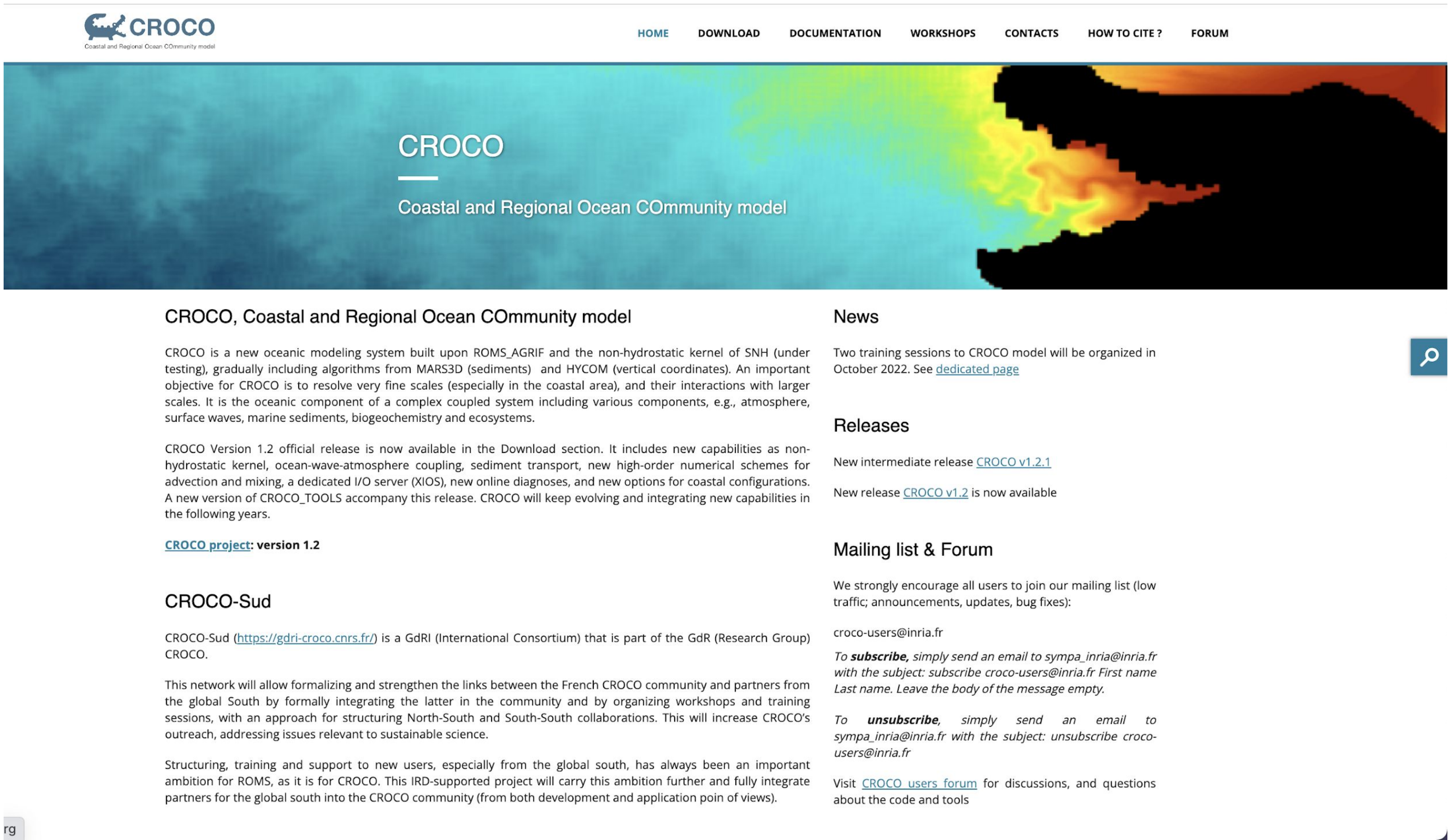
- NetCDF : http://www.unidata.ucar.edu

Additional software

- Ncview
- NCO
- Ferret
- Octave-3.6.1 + octcdf 1.1.5

How to get the tools?

http://www.croco-ocean.org


CROCO
Coastal and Regional Ocean COmmunity model

HOME DOWNLOAD DOCUMENTATION WORKSHOPS CONTACTS HOW TO CITE ? FORUM

CROCO
Coastal and Regional Ocean COmmunity model

CROCO, Coastal and Regional Ocean COmmunity model

CROCO is a new oceanic modeling system built upon ROMS_AGRIF and the non-hydrostatic kernel of SNH (under testing), gradually including algorithms from MARS3D (sediments) and HYCOM (vertical coordinates). An important objective for CROCO is to resolve very fine scales (especially in the coastal area), and their interactions with larger scales. It is the oceanic component of a complex coupled system including various components, e.g., atmosphere, surface waves, marine sediments, biogeochemistry and ecosystems.

CROCO Version 1.2 official release is now available in the Download section. It includes new capabilities as non-hydrostatic kernel, ocean-wave-atmosphere coupling, sediment transport, new high-order numerical schemes for advection and mixing, a dedicated I/O server (XIOS), new online diagnoses, and new options for coastal configurations. A new version of CROCO_TOOLS accompany this release. CROCO will keep evolving and integrating new capabilities in the following years.

CROCO project: version 1.2

CROCO-Sud

CROCO-Sud (https://gdri-croco.cnrs.fr/) is a GdRI (International Consortium) that is part of the GdR (Research Group) CROCO.

This network will allow formalizing and strengthen the links between the French CROCO community and partners from the global South by formally integrating the latter in the community and by organizing workshops and training sessions, with an approach for structuring North-South and South-South collaborations. This will increase CROCO's outreach, addressing issues relevant to sustainable science.

Structuring, training and support to new users, especially from the global south, has always been an important ambition for ROMS, as it is for CROCO. This IRD-supported project will carry this ambition further and fully integrate partners for the global south into the CROCO community (from both development and application poin of views).

News

Two training sessions to CROCO model will be organized in October 2022. See dedicated page

Releases

New intermediate release CROCO v1.2.1

New release CROCO v1.2 is now available

Mailing list & Forum

We strongly encourage all users to join our mailing list (low traffic; announcements, updates, bug fixes):

croco-users@inria.fr

*To **subscribe**, simply send an email to sympa_inria@inria.fr with the subject: subscribe croco-users@inria.fr First name Last name. Leave the body of the message empty.*

*To **unsubscribe**, simply send an email to sympa_inria@inria.fr with the subject: unsubscribe croco-users@inria.fr*

Visit CROCO users forum for discussions, and questions about the code and tools

- **In the download section**
  - **CROCO** : Fortran source code
  - **CROCO_TOOLS** : Pre- and post
  - processing toolbox (Matlab)
  - **DATASETS** [18 Gb] : the global datasets needed by the CROCO_TOOLS
  - **UTILITIES** : netCDF library, mapping toolbox etc …

A modeling package

CROCO
Coastal and Regional Ocean COmmunity model

croco_tools : Matlab pre-post processing toolbox

- Aforc_NCEP
- Aforc_QuikSCAT
- Diagnostic_tools
- Nesting_tools
- Opendap_tools
- Opendap_tools_no_loaddap
- RUNOFF_DAI
- Tides
- Town
- UTILITIES
- Visualization_tools
- croco_pytools
- croco_pyvisu
- start.m
- Oforc_OGCM
- Aforc_CFSR
- Aforc_ECMWF
- Coupling_tools
- Rivers
- crocotools_param.m
- readme_version_croco_tools.txt
- Forecast_tools
- Preprocessing_tools

UTILITIES:

- air_sea
- export_fig
- m_map1.4h
- mask
- mex60
- mexcdf
- netcdf_matlab_60
- netcdf_x86_64

CROCO : Fortran source code

- AGRIF
- CVTK
- OCEAN
- PISCES
- Run
- XIOS
- create_config.bash

DATA_SETS : Global datasets to build the regional forcing

- CARS2009
- COADS05
- GOT99.2
- m_map1.4f
- QuikSCAT_clim
- RUNOFF_DAI
- SeaWifs
- SST_pathfinder
- Topo
- TPXO6
- TPXO7
- WOA2009
- WOAPISCES

On Seolane server

```
ssh -X userX@172.20.254.3
mkdir TRAINING_2023
cd TRAINING_2023

# alias of the dataset directory
ln -sf /home/COMMONDATA/data_tutos/DATASETS_CROCOTOOLS ~/TRAINING_2023/CROCO/croco_tools/.
```

CROCO architecture

CROCO
Coastal and Regional Ocean COmmunity model

DATA

bathy, initial and boundary conditions, surface forcing, tides, rivers...

CROCO_DATASETS (climatology)
Interannual datasets (e.g. Mercator, ERA5…)

croco_tools

Tools for pre-processing, post-processing, diagnoses, visualisation

Matlab tools
Python tools

croco

Model, libraries (e.g. AGRIF) interfaces with other models, and scripts for running simulations

Model sources
Libraries
Scripts for run

CONFIGS

Where you will design and run your configurations

CROCO architecture

CROCO
Coastal and Regional Ocean COmmunity model

DATA

bathy, initial and boundary conditions, surface forcing, tides, rivers…

CROCO_DATASETS (climatology)

```
CARS2009
COADS05
GOT99.2
GSHHS
m_map1.4f
QuikSCAT_clim
RUNOFF_DAI
SeaWifs
SST_pathfinder
Topo
TPX06
TPX07
WOA2009
WOAPISCES
```

croco_tools

Tools for pre-processing, post-processing, diagnoses, visualisation

```
Aforc_CFSR
Aforc_ECMWF
Aforc_ERA5
Aforc_NCEP
Aforc_QuikSCAT
Coupling_tools
croco_pyvisu
crocotools_param.m
Diagnostic_tools
example_job_prepro_matlab.pbs
Forecast_tools
job_prepro_matlab.pbs
Nesting_tools
oct_start.m
Oforc_OGCM
Opendap_tools
Opendap_tools_no_loaddap
Preprocessing_tools
readme_version_croco_tools.txt
Rivers
RUNOFF_DAI
start.m
Tides
Town
UTILITIES
Visualization_tools
```

croco

Model, libraries (e.g. AGRIF) interfaces with other models, and scripts for running simulations

```
AGRIF
create_config.bash
CVTK
DOC_SPHINX
MPI_NOLAND_preprocessing
MUSTANG
OCEAN
PISCES
README.md
SCRIPTS
TEST_CASES
XIOS
```

Climatology simulation

1) Crocotools presentation for preprocessing

2) Climatology simulation (simulation with no restart)

3) Inter annual simulation

Strategy to build a configuration

CROCO
Coastal and Regional Ocean COmmunity model

cd $HOME/TRAINING_2023

cp CROCO/croco/create_config.bash .

=> Edit create_config.bash
(e.g. with vi)

Note : 3 options of configuration architectures available :
"all-dev": for dev of analytical tests
"all-prod": for production climatological / interannual simulations => provides additional scripts
"all-prod-cpl" : for coupled simulations (ww3, wrf)=> provides additional scripts
=> choose « all-prod »

```
# croco source directory
# -----------------------
CROCO_DIR=/home/user30/TRAINING_2023/CROCO/croco

# croco_tools directory
# ---------------------
TOOLS_DIR=/home/user30/TRAINING_2023/CROCO/croco_tools

# Configuration name
# ------------------
MY_CONFIG_NAME=BENGUELA_LR

# Home and Work configuration directories
# ---------------------------------------
MY_CONFIG_HOME=/home/user30/TRAINING_2023/CONFIGS
MY_CONFIG_WORK=/home/user30/TRAINING_2023/CONFIGS

# Options of your configuration
# -----------------------------
## default option : all-dev for the usual ("all-in") archi
options=( all-prod )
```

Strategy to build a configuration

Run the create_config script:
./create_config.bash

=> It will create a BENGUELA_LR configuration in your CONFIGS directory

cd CONFIGS/BENGUELA_LR
ls -l

```
create_config.bash.bck
CROCO_FILES
CROCO_IN
DATA
myenv_mypath.sh
myjob.sh
mynamelist.sh
PREPRO
README_coupling_tools
run_croco.bash
run_croco_forecast.bash
run_croco_inter.bash
SCRIPTS_TOOLBOX
submitjob.sh
```

Strategy to build a configuration

CROCO
Coastal and Regional Ocean COmmunity model

cd $HOME/TRAINING_2023/CONFIGS/BENGUELA_LR

General architecture of the configuration folder:

create_config.bash.bck ---------------- Backup of create_config script
myenv_mypath.sh ---------------- Environment file

PREPRO ---------------- Directory for preprocessing
CROCO_IN ---------------- Directory for CROCO compilation and settings
CROCO_FILES ---------------- Directory for CROCO inputs and outputs files
SCRATCH ---------------- Directory where the run is executed

run_croco.bash ---------------- Script for launching climatological runs
run_croco_inter.bash ---------------- Script for launching interannual runs
run_croco_forecast.bash ------------ Script for launching forecast runs

mynamelist.sh
myjob.sh
submitjob.sh
SCRIPTS_TOOLBOX

---------------- Scripts for setting and launching simulation with the coupling toolbox

```
create_config.bash.bck
CROCO_FILES
CROCO_IN
DATA
myenv_mypath.sh
myjob.sh
mynamelist.sh
PREPRO
README_coupling_tools
run_croco.bash
run_croco_forecast.bash
run_croco_inter.bash
SCRIPTS_TOOLBOX
```

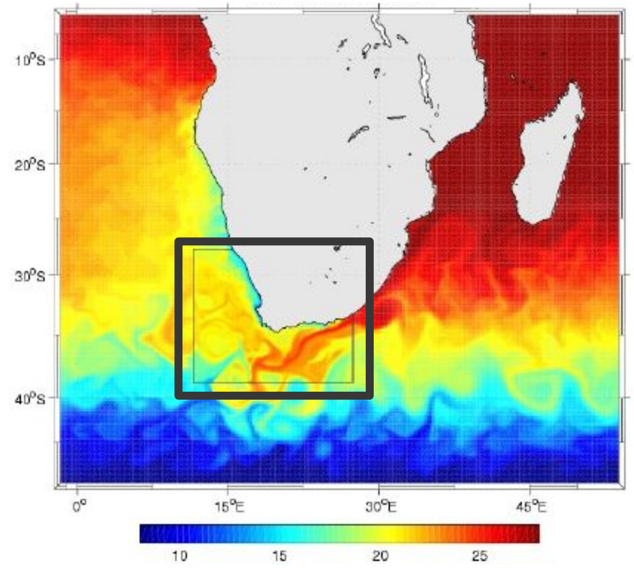
I-Preprocessing

cd $HOME/TRAINING_2023/CONFIGS/BENGUELA_LR

cd PREPRO/CROCO
ls -l

```
crocotools_param.m
find_childgrid_inparentgrid.m
job_prepro_matlab.pbs
make_grid_from_WRF.m
oct_start.m
prepro_cfsr.m
prepro_soda.m
README_nest_cpl
README_preprocess_croco
start.m
town.dat
```

Description of the benguela configuration



A regional realistic configuration , atmospheric forcing only
no tides
realistic bathymetry and stratification
horizontal resolution dl = 1/3° (33 km)
vertical resolution : N=32

```
theta_s    =  7.;
theta_b    =  2.;
hc         = 200.;
vtransform =  2.; % s-coordinate type (1: old- ; 2: new- coordinates)
                  % ! take care to define NEW_S_COORD cpp-key in cppdefs.h
```

=> better discretization on surface layers

Tutorial to follow

CROCO
Coastal and Regional Ocean COmmunity model

https://croco-ocean.gitlabpages.inria.fr/croco_doc/tutos/tutos.04.config.html

Croco Doc

Search docs

6. Regional: Preparing your configuration

To prepare your configuration working directory, you can use the script `create_config.bash` provided in CROCO sources:

```
cp ~/croco/croco/create_config.bash ~/CONFIGS/.
```

Edit your paths and settings in `create_config.bash`:

```
#==========================================================================================
# BEGIN USER MODIFICATIONS

# Machine you are working on
# Known machines: Linux DATARMOR IRENE JEANZAY
# ---------------------------------------------
MACHINE="Linux"

# CROCO parent directory
# (where croco_tools directory and croco source directory can be found)
# -----------------
CROCO_DIR=~/croco/croco
TOOLS_DIR=~/croco/croco_tools

# Configuration name
# ------------------
MY_CONFIG_NAME=BENGUELA_LR

# Home and Work configuration directories
```

How to build input files using CROCO_TOOLS ?

Documentation :
https://croco-ocean.gitlabpages.inria.fr/croco_doc/tutos/tutos.04.config.html

7. Regional: Preprocessing (Matlab)

CROCO preprocessing tools have been developed under Matlab software by IRD researchers (former Roms_tools). Note: These tools have been made to build easily regional configurations using climatological data. To use interannual data, some facilities are available (NCEP, CFSR, QuickScat data for atmospheric forcing, SODA and ECCO for lateral boundaries). However, to use other data, you will need to adapt the scripts. All utilities/toolbox requested for matlab crocotools programs are provided within the UTILITIES directory, or can be downloaded here: http://www.croco-ocean.org/download/utilities/

Previous

Next

The crocotools_param.m files

`crocotools_param.m` is separated into several sections:

1 - Configuration parameters	used by make_grid.m (and others..)
2 - Generic file and directory names	need to match your work architecture
3 - Surface forcing parameters	used by make_forcing.m and by make_bulk.m
4 - Open boundaries and initial conditions parameters	used by make_clim.m, make_biol.m, make_bry.m make_OGCM.m and make_OGCM_frcst.m
5 - Parameters for tidal forcing	used by make_tides.m
6 - Reference date and simulation times	used for make_tides, make_CFSR (or make_NCEP), make_OG(
7 - Parameters for Interannual forcing	SODA, ECCO, CFSR, NCEP, ...
8 - Parameters for the forecast system	used by make_forecast.m
9 - Parameters for the diagnostic tools	used by scripts in `Diagnostic_tools`

https://croco-ocean.gitlabpages.inria.fr/croco_doc/tutos/tutos.05.prepro.matlab.clim.html

Building the grid

Launch matlab session

cd $HOME/TRAINING_2023/CONFIGS/BENGUELA_LR/PREPRO/CROCO

matlab -nodesktop

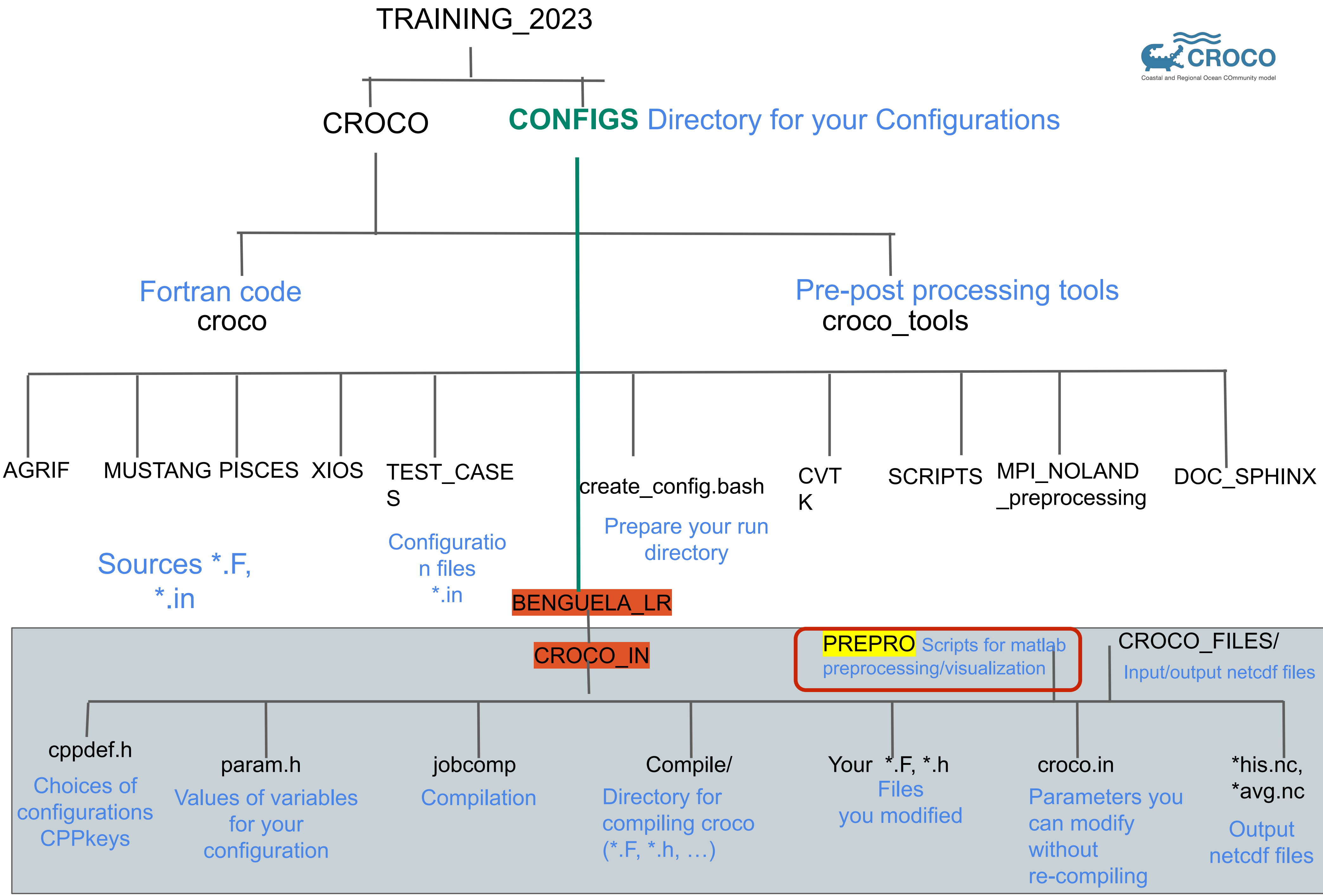
Section 1 in crocotools_param.m

```
%
% 1 - Configuration parameters
% used by make_grid.m (and others..)
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
isoctave=exist('octave_config_info');
%
% CROCO title names and directories
%
CROCO_title = 'Benguela Model';
CROCO_config = 'Benguela_LR';
%
% Grid dimensions:
%
lonmin = 8; % Minimum longitude [degree east]
lonmax = 22; % Maximum longitude [degree east]
latmin = -38; % Minimum latitude [degree north]
latmax = -26; % 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 croco.in !)
%
theta_s = 7.;
theta_b = 2.;
hc = 200.;
vtransform = 2.; % s-coordinate type (1: old- ; 2: new- coordinates)
% ! take care to define NEW_S_COORD cpp-key in cppdefs.h
%
% Topography: choice of filter
%
topo_smooth = 1; % 1: old ; 2: new filter (better but slower)
%
% 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;

....
```

caution: if h<hmin, then h=hmin !!!

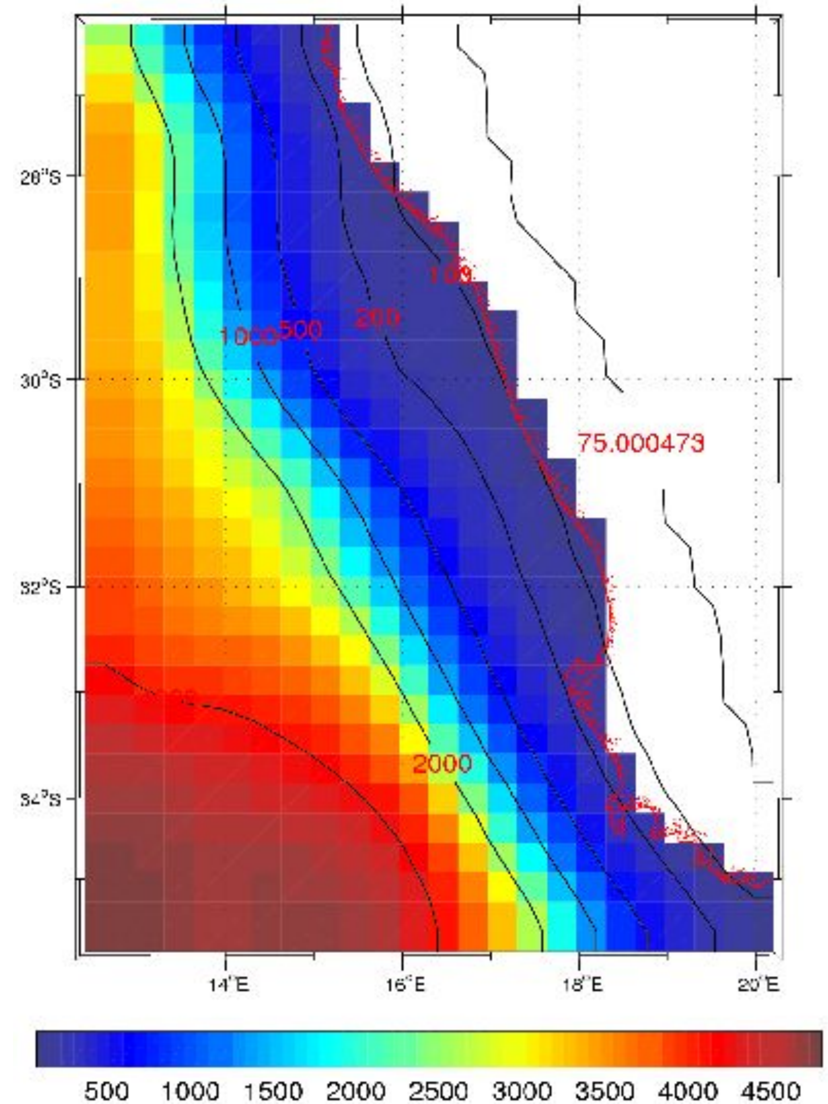
```
129 %
130 makeplot      = 1;        % 1: create graphics after each preprocessing step
131 %
```


TRAINING_2023
CRoco
Coastal and Regional Ocean COmmunity model
CROCO
CONFIGS Directory for your Configurations
Fortran code
croco
Pre-post processing tools
croco_tools
AGRIF
MUSTANG
PISCES
XIOS
TEST_CASES
Sources *.F, *.in
Configuration files *.in
create_config.bash
Prepare your run directory
CVTK
SCRIPTS
MPI_NOLAND_preprocessing
DOC_SPHINX
BENGUELA_LR
CROCO_IN
PREPRO Scripts for matlab preprocessing/visualization
CROCO_FILES/
Input/output netcdf files
cppdef.h
Choices of configurations CPPkeys
param.h
Values of variables for your configuration
jobcomp
Compilation
Compile/
Directory for compiling croco (*.F, *.h, …)
Your *.F, *.h Files you modified
croco.in
Parameters you can modify without re-compiling
*his.nc, *avg.nc
Output netcdf files

Building the grid

make_grid.m , create the input file croco_grd.nc

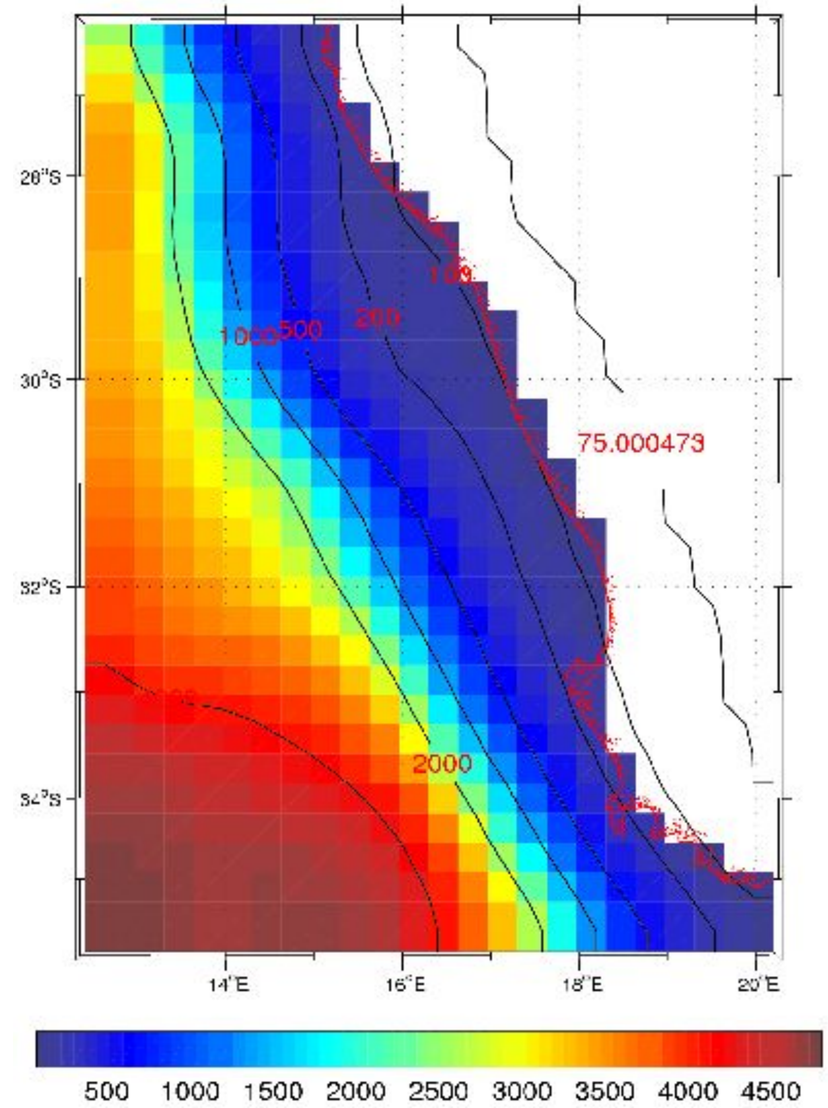
```
Making the grid:
/home1/datawork/gcambon/TRAINING_2019/CONFIGS/Run_BENGUELA_LR/CROCO_FI
LES/croco_grd.nc

 Title: Benguela Model
 Resolution: 1/3 deg

 Do you want to use interactive grid maker ?
 (e.g., for grid rotation or parameter adjustments) : y,[n] n

 Create the grid file...
 LLm = 41
 MMm = 42

 Fill the grid file...
 Compute the metrics...
 Min dx=29.1913 km - Max dx=33.3244 km
 Min dy=29.2434 km - Max dy=33.1967 km
 Fill the grid file...
 Add topography...
   CROCO resolution : 31.3 km
   Topography data resolution : 3.42 km
   Topography resolution halved 4 times
   New topography resolution : 54.6 km
Processing coastline_l.mat ...

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



Building the grid

```
Making the grid:
/home1/datawork/gcambon/TRAINING_2019/CONFIGS/Run_BENGUELA_LR/CROCO_FI
LES/croco_grd.nc

 Title: Benguela Model
 Resolution: 1/3 deg

 Do you want to use interactive grid maker ?
 (e.g., for grid rotation or parameter adjustments) : y,[n] n

 Create the grid file...
 LLm = 41
 MMm = 42

 Fill the grid file...
 Compute the metrics...
 Min dx=29.1913 km - Max dx=33.3244 km
 Min dy=29.2434 km - Max dy=33.1967 km
 Fill the grid file...
 Add topography...
   CROCO resolution : 31.3 km
   Topography data resolution : 3.42 km
   Topography resolution halved 4 times
   New topography resolution : 54.6 km
Processing coastline_l.mat ...

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

same as in param.h !!!!



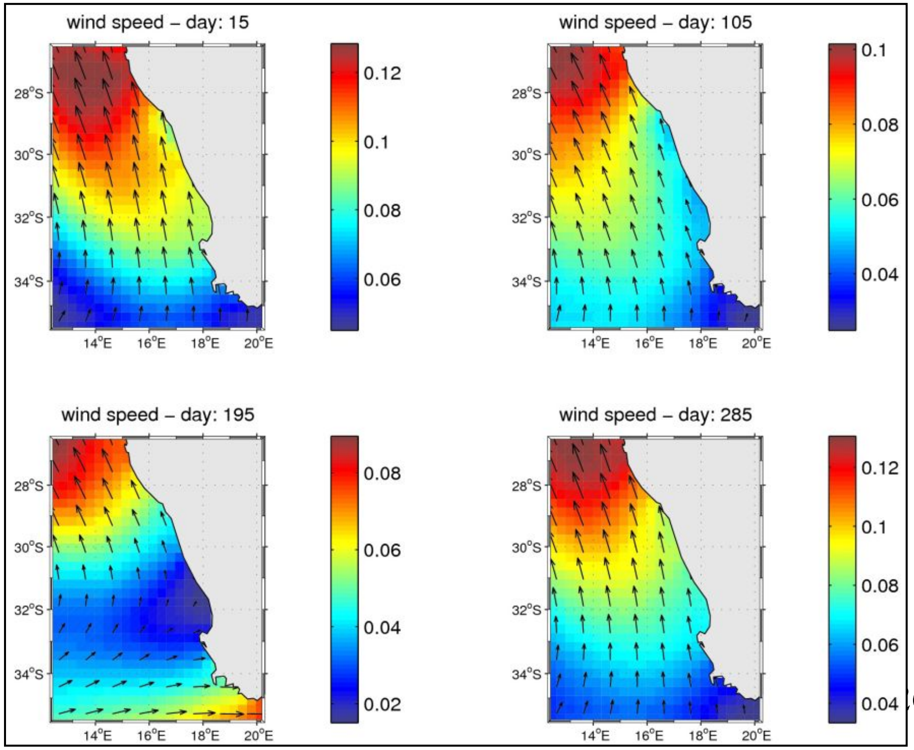
Build the atmospheric surface boundary forcing

make_forcing .m □ create the input file croco_frc.nc

Section 3 crocotools_param.m

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% COADS directory (for climatology runs)
%
coads_dir=[DATADIR,'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
%
%coads_time=(15.2188:30.4375:350.0313); % year of 365.25 days in case
%coads_cycle=365.25; % interannual QSCAT winds
% % are used with clim. heat flux
%
% Pathfinder SST data used by pathfinder_sst.m
%
pathfinder_sst_name=[DATADIR,...
'SST_pathfinder/climato_pathfinder.nc'];
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
Benguela Model

 Read in the grid...

 Create the forcing file...
Getting taux for time index 1
Getting tauy for time index 1
Getting taux for time index 2
Getting tauy for time index 2
Getting taux for time index 3
Getting tauy for time index 3
…
Getting shortrad for time index 9
Getting shortrad for time index 10
Getting shortrad for time index 11
Getting shortrad for time index 12
```



Build the atmospheric forcing: 2 options are available:

- create a forcing file with wind stress (zonal and meridional components), surface net heat flux, surface freshwater flux (E-P), solar shortwave radiation, SST, SSS, surface net sensitivity to SST (used for heat flux correction dQdSST for nudging towards model SST and model SSS)
- or create a bulk file which will be read during the run to perform bulk parameterization of the fluxes using COAMPS or Fairall 2003 formulation. This bulk file contains: surface air temperature, relative humidity, precipitation rate, wind speed at 10m, net outgoing longwave radiation, downward longwave radiation, shortwave radiation, surface wind speed (zonal and meridional components). It also contains surface wind stress (zonal and meridional components), but it is not requested and used in the model (except for specific debugging work). The bulk formulation computes its own wind stress.

```
make_bulk
```

or:

```
make_forcing
```

The settings relative to surface forcing are in section 3 of `crocotools_param.m`. In the case of climatological forcing, the variables are cycled. You can see that here, for the sake of simplicity, we are running the model on a repeating climatological year of 360 days.

A few figures illustrate the wind stress vectors and norm at 4 different periods of the year.

> **Note**
>
> `make_bulk` creates a forcing file that will be used with the cpp key `BULK_FLUX`, while `make_forcing` creates a forcing file containing wind stress directly and will be used when `undefined BULK_FLUX`. This second option is relevant if your atmospheric forcing comes from an atmospheric model with sufficient output frequency, or/and if your are comparing forced and coupled runs. Otherwise it is suggested to use `make_bulk`.

Build the initial/open boundary oceanic conditions

Section 4 in crocotools_param.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;
%
%  initial/boundary data options (1 = process)
%  (used in make_clim, make_biol, make_bry,
%   make_OGCM.m and make_OGCM_frcst.m)
%
makeini    = 1;   % initial data
makeclim   = 1;   % climatological data (for boundaries and nudging layers)
makebry    = 1;   % lateral boundary data
makenpzd   = 0;   % initial and boundary data for NChlPZD and N2ChlPZD2
models
makebioebus= 0;   % initial and boundary data for BioEBUS model
makepisces = 0;   % initial and boundary data for PISCES model
%
%
makeoa     = 1;   % oa data (intermediate file)
makeZbry   = 1;   % boundary data in Z coordinate (intermediate file)
insitu2pot = 1;   % transform in-situ temperature to potential temperature
%
%  Day of initialisation for climatology experiments (=0 : 1st january 0h)
%
tini=0;
%
```

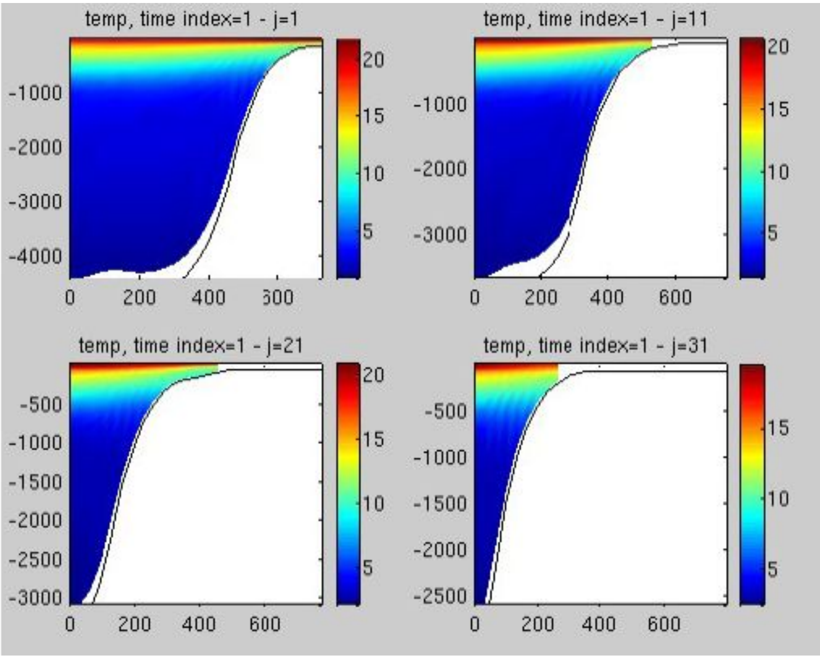
```
%
% Pisces biogeochemical seasonal climatology
%
woapisces_dir = [DATADIR,'WOAPISCES/'];  % only compatible with woa_dir
%
% Surface chlorophyll seasonal climatology (SeaWifs)
%
chla_dir=[DATADIR,'SeaWifs/'];
%
% Runoff monthly seasonal climatology (Dai and Trenberth)
%
global_clim_riverdir=[DATADIR,'RUNOFF_DAI/'];
global_clim_rivername=[global_clim_riverdir,'Dai_Trenberth_runoff_global
_clim.nc'];
%
%  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
%
```

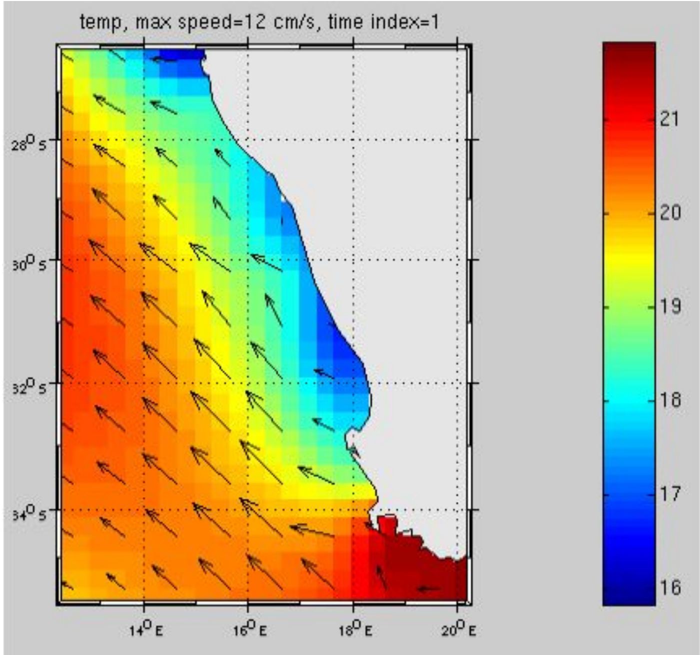
Build the initial oceanic conditions

CROCO
Coastal and Regional Ocean COmmunity model

> make_ini.m □ create croco_ini.nc

```
Benguela Model
Making initial file:
/home1/datawork/gcambon/TRAINING_2019/CONFIGS/Run_BENGUELA
_LR/CROCO_FILES/croco_ini.nc

 Title: Climatology

 Creating the file :
/home1/datawork/gcambon/TRAINING_2019/CONFIGS/Run_BENGUELA
_LR/CROCO_FILES/croco_ini.nc
 VTRANSFORM = 2

 Interpolations / extrapolations

 Temperature...

 Ext tracers: ro = 0 km - default value = NaN
   ext_tracers_ini: time index: 1 of total: 12
   ext_tracers_ini: horizontal interpolation of seasonal data
   ext_tracers_ini: vertical interpolation

 Salinity...

 Ext tracers: ro = 0 km - default value = NaN
   ext_tracers_ini: time index: 1 of total: 12
   ext_tracers_ini: horizontal interpolation of seasonal data
   ext_tracers_ini: vertical interpolation

 Compute potential temperature from in-situ...
   getpot: Time index: 1 of total: 1
```





Build the Open boundary oceanic conditions : clm type [old way]

> make_clim.m create croco_clm.nc

```
Creating the file :
/home1/datawork/gcambon/TRAINING_2019/CONFIGS/Run_BENGUELA
_LR/CROCO_FILES/croco_clm.nc

 VTRANSFORM = 2

         NetCDF_File:
'/home1/datawork/gcambon/TRAINING_2019/CONFIGS/Run_BENGUELA
_LR/CROCO_FILES/croco_clm.nc'
         nDimensions: 20
          nVariables: 31
    nGlobalAttributes: 0
      RecordDimension: ''
            nRecords: 0
          Permission: 'clobber'
          DefineMode: 'define'
            FillMode: 'fill'
          MaxNameLen: 0

 Create the OA file...

 Creating the file :
/home1/datawork/gcambon/TRAINING_2019/CONFIGS/Run_BENGUELA
_LR/CROCO_FILES/croco_oa.nc

 Horizontal extrapolations
 Temperature...

 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: 12
…
time index: 12 of total: 12
```

```
Salinity...

 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: 12
…
Vertical interpolations

 Temperature...
 Time index: 1 of total: 12
…

 Compute potential temperature from in-situ...
   getpot: Time index: 1 of total: 12
…
Compute geostrophic currents
time index: 1 of total: 12
Flux correction : -7.2065
Mask: 16 iterations
…
```

Open boundary oceanic conditions : bry type [recommended]

> make_bry.m create croco_bry.nc

```
Create the boundary file...
 Creating the file :
/home1/datawork/gcambon/TRAINING_2019/CONFIGS/Run_BENGUELA_LR/CROCO_FILES/croco_bry.nc

 VTRANSFORM = 2

nc =

        NetCDF_File: '/home1/datawork/gcambon/TRAINING_2019/CONFIGS/Run_BENGUELA_LR/CROCO_FILES/croco_bry.nc'
        nDimensions: 21
         nVariables: 10
   nGlobalAttributes: 0
     RecordDimension: ''
           nRecords: 0
         Permission: 'clobber'
         DefineMode: 'define'
           FillMode: 'fill'
         MaxNameLen: 0

 Create the boundary Z-file...

 Creating the file :
/home1/datawork/gcambon/TRAINING_2019/CONFIGS/Run_BENGUELA_LR/CROCO_FILES/croco_bry_Z.nc

 Horizontal extrapolations
 Processing southern boundary...
  Temperature...
 Ext tracers: horizontal interpolation of the annual data
 Ext tracers: horizontal interpolation of the seasonal data
time index: 1 of total: 12
```

Summary for pre-processing input files [climato]

cd $HOME/TRAINING_2023/CONFIGS/BENGUELA_LR/PREPRO/CROCO

matlab &

>> **start** : Add all the needed matlab path of the system

>> **make_grid**
=> creates CROCO_FILES/croco_grd.nc
- Horizontal grid : position of the grid points, size of the grid cells
- Bottom topography
- Land mask

>> **make_forcing**
=> create CROCO_FILES/croco_frc.nc
- Surface forcing : wind stress, surface heat flux, surface freshwater flux

>> **make_ini**
=> creates CROCO_FILES/croco_ini.nc
initial conditions : T, S, currents , SSH

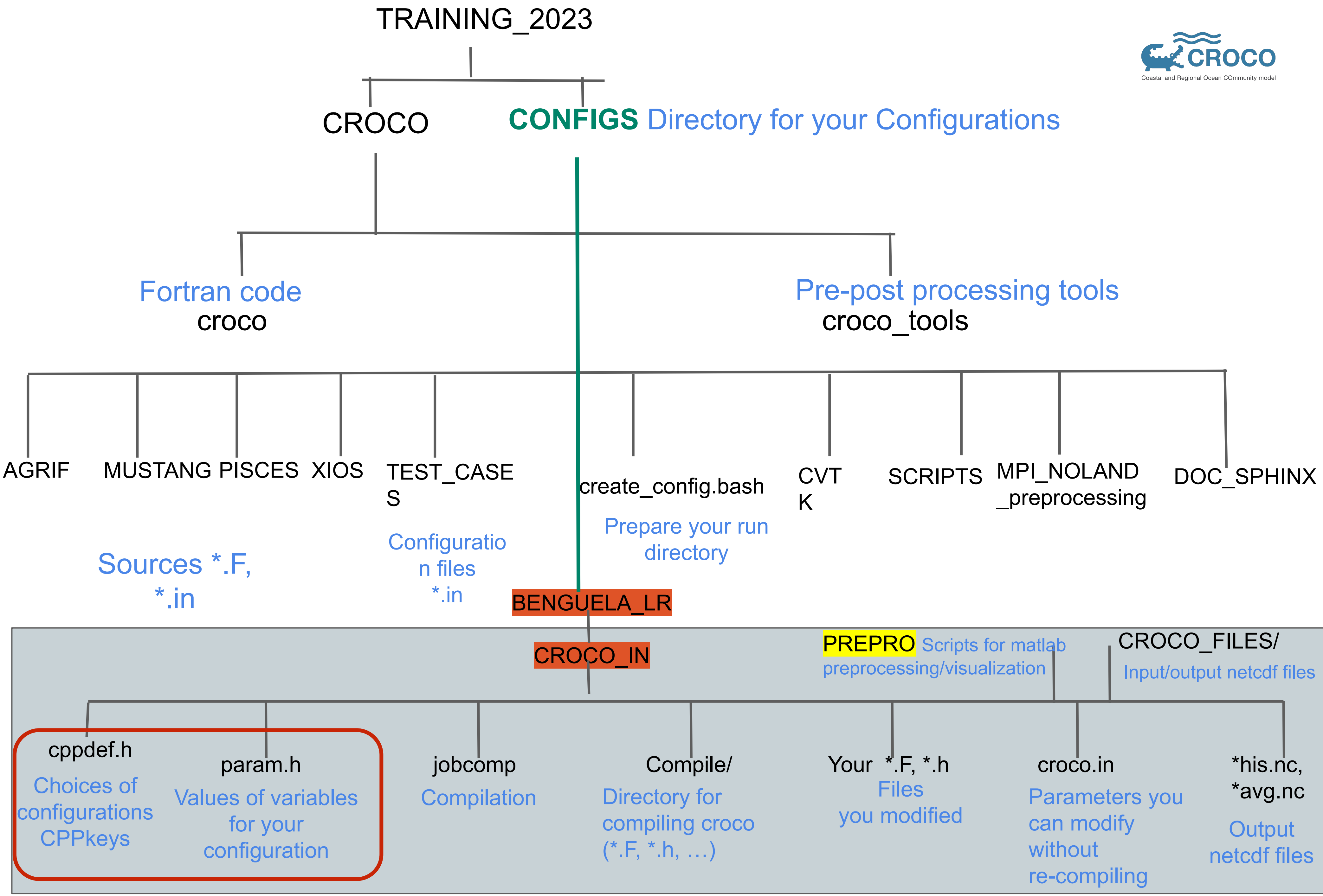
>> **make_clim** (or **make_bry**)
=> creates CROCO_FILES/croco_clm.nc (or . croco_bry.nc)
- Lateral oceanic boundary conditions T, S, currents , SSH

make_forcing
to generate an atmospheric forcing file

↓

make_clim , make_bry
- u= geostrophic currents+ eckman transport

to generate an OBC forcing file
- T, S from COADS dataset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cppdef.h
Choices of configurations CPPkeys
param.h
Values of variables for your configuration
jobcomp
Compilation
Compile/
Directory for compiling croco (*.F, *.h, …)
Your *.F, *.h Files you modified
croco.in
Parameters you can modify without re-compiling
*his.nc, *avg.nc
Output netcdf files

Configuring the model CROCO

cd ~/TRAINING_2023/CONFIGS/BENGUELA_LR/CROCO_IN

```
#if defined REGIONAL
/*
!=================================================================          REGIONAL (realistic) Configurations
!=================================================================
!
!----------------------
! BASIC OPTIONS
!----------------------
!
*/
                 /* Configuration Name */
# define BENGUELA_LR
                 /* Parallelization */
# undef  OPENMP
# define  MPI
# undef  MPI_NOLAND
                 /* I/O server */
# undef  XIOS
# undef  XIOS2
                 /* Non-hydrostatic option */
# undef  NBQ
                 /* Nesting */
# undef  AGRIF
# undef  AGRIF_2WAY
                 /* OA and OW Coupling via OASIS (MPI) */
# undef  OA_COUPLING
# undef  OW_COUPLING
                 /* Wave-current interactions */
# undef  MRL_WCI
                 /* Open Boundary Conditions */
# undef  TIDES
# define OBC_EAST
# define OBC_WEST
# define OBC_NORTH
# define OBC_SOUTH

/* Applications */
# undef  BIOLOGY
# undef  FLOATS
# undef  STATIONS
# undef  PASSIVE_TRACER
# undef  SEDIMENT
# undef  BBL
                 /* dedicated croco.log file */
# undef  LOGFILE
                 /* Calendar */
# undef  USE_CALENDAR
/*!
!-------------------------------------------------
! PRE-SELECTED OPTIONS
!
! ADVANCED OPTIONS ARE IN CPPDEFS_DEV.H
!-------------------------------------------------
*/
                 /* Parallelization */
# ifdef MPI
#  undef  PARALLEL_FILES
# endif
# undef  NC4PAR
# undef  AUTOTILING
                 /* Non-hydrostatic options */
# ifdef NBQ
#  define W_HADV_TVD
#  define W_VADV_TVD
# endif

/* Grid configuration */
# define CURVGRID
# define SPHERICAL
# define MASKING
# undef  WET_DRY
# define NEW_S_COORD
                 /* Model dynamics */
# define SOLVE3D
# define UV_COR
# define UV_ADV
```

cppdefs.h file (1/2)

Configuring the model CROCO


```
 /* Equation of State */
# define SALINITY
# define NONLIN_EOS
                /* Lateral Momentum Advection (default UP3) */
# define UV_HADV_UP3
# undef  UV_HADV_UP5
# undef  UV_HADV_WENO5
# undef  UV_HADV_TVD
                /* Lateral Explicit Momentum Mixing */
# undef  UV_VIS2
# ifdef UV_VIS2
#  define UV_VIS_SMAGO
# endif
                /* Vertical Momentum Advection  */
# define UV_VADV_SPLINES
# undef  UV_VADV_WENO5
# undef  UV_VADV_TVD
                /* Lateral Tracer Advection (default UP3) */
# undef  TS_HADV_UP3
# define TS_HADV_RSUP3
# undef  TS_HADV_UP5
# undef  TS_HADV_WENO5
                /* Lateral Explicit Tracer Mixing */
# undef  TS_DIF2
# undef  TS_DIF4
# undef  TS_MIX_S
                /* Vertical Tracer Advection  */
# undef  TS_VADV_SPLINES
# define TS_VADV_AKIMA
# undef  TS_VADV_WENO5
                /* Sponge layers for UV and TS */
# define SPONGE
```

```
        /* Semi-implicit Vertical Tracer/Mom
Advection */
# undef  VADV_ADAPT_IMP
                /* Bottom friction in fast 3D step
*/
# undef  BSTRESS_FAST
                /* Vertical Mixing */
# undef  BODYFORCE
# undef  BVF_MIXING
# define LMD_MIXING
# undef  GLS_MIXING
# ifdef LMD_MIXING
#  define LMD_SKPP
#  define LMD_BKPP
#  define LMD_RIMIX
#  define LMD_CONVEC
#  undef  LMD_DDMIX
#  define LMD_NONLOCAL
#  undef  MLCONVEC
# endif
                /* Surface Forcing */
# undef BULK_FLUX
# ifdef BULK_FLUX
#  define BULK_FAIRALL
#  define BULK_LW
#  define BULK_EP
#  define BULK_SMFLUX
#  undef  SST_SKIN
#  undef  ANA_DIURNAL_SW
#  undef  ONLINE#  ifdef ONLINE
#   undef  AROME
#   undef  ERA_ECMWF
#  endif
```

```
#  undef READ_PATM
#  ifdef READ_PATM
#   define OBC_PATM
#  endif
# else
#  define QCORRECTION
#  define SFLX_CORR
#  undef  SFLX_CORR_COEF
#  define ANA_DIURNAL_SW
# endif
# undef SMFLUX_CFB
# undef  SEA_ICE_NOFLUX
                /* Wave-current interactions */
# ifdef OW_COUPLING
#  define MRL_WCI
#  define BBL
# endif
# ifdef MRL_WCI
#  ifndef OW_COUPLING
#   define WAVE_OFFLINE
#   undef  WKB_WWAVE
#  endif
#  undef  WAVE_ROLLER
#  define WAVE_STREAMING
#  define WAVE_FRICTION
#  define WAVE_RAMP
#  ifdef WKB_WWAVE
#   undef  WKB_OBC_NORTH
#   undef  WKB_OBC_SOUTH
#   undef  WKB_OBC_WEST
#   undef  WKB_OBC_EAST
#  endif
# endif
```

cppdefs.h file (2/2)

Configuring the model CROCO

Array dimensions and parameters (param.h)

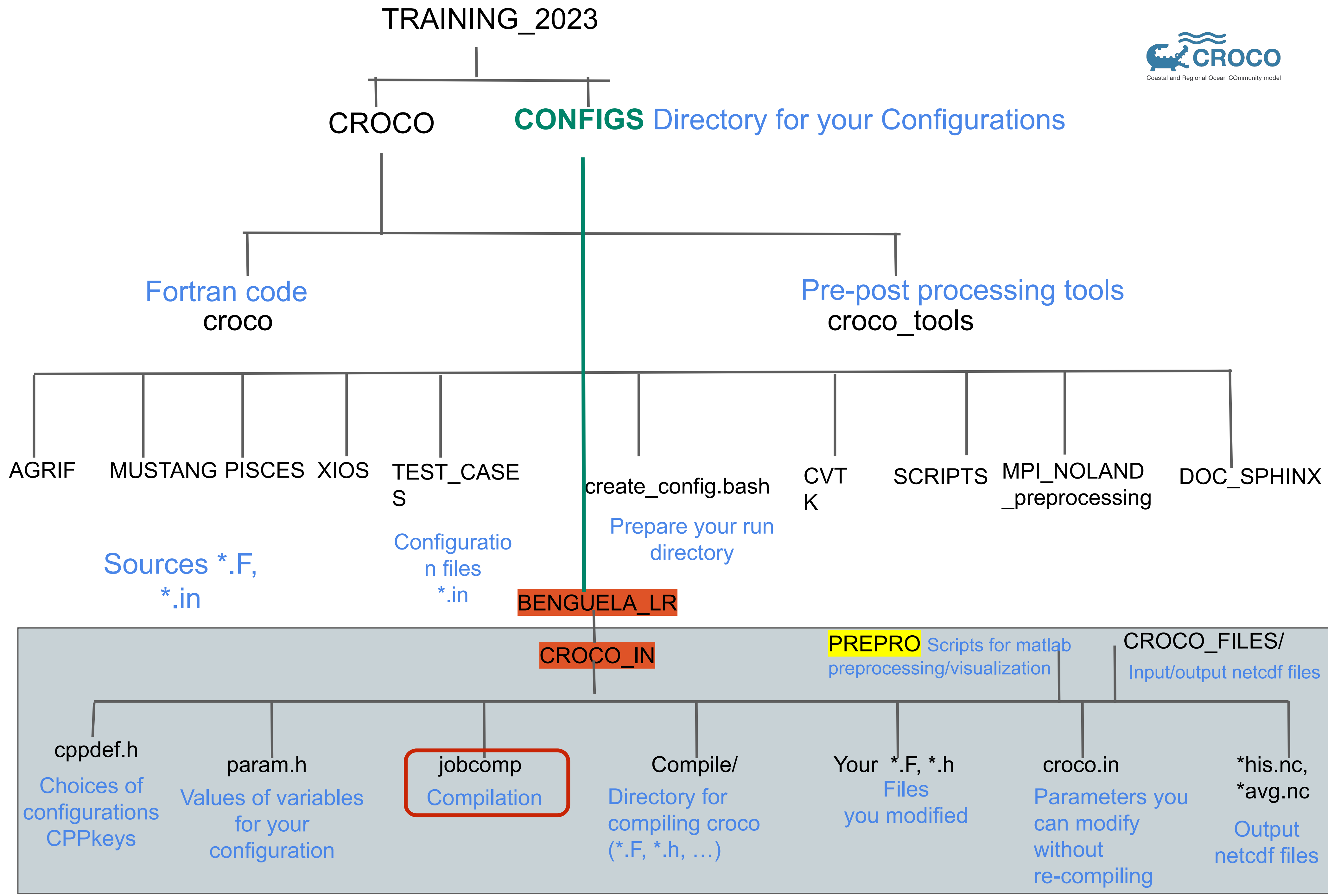
```
!----------------------------------------------------------------------
! Dimensions of Physical Grid and array dimensions
!----------------------------------------------------------------------
!
! LLm,MMm  Number of the internal points of the PHYSICAL grid.
!          in the XI- and ETA-directions [physical side boundary
!          points and peroodic ghost points (if any) are excluded].
!
! Lm,Mm    Number of the internal points [see above] of array
!          covering a Message Passing subdomain. In the case when
!          no Message Passing partitioning is used, these two are
!          the same as LLm,MMm.
!
! N        Number of vertical levels.
!
      integer  LLm,Lm,MMm,Mm,N, LLm0,MMm0
#if defined AGRIF
      integer LLmm2, MMmm2
#endif
#if defined BASIN
      parameter (LLm0=60,   MMm0=50,   N=10)
#elif defined CANYON_A
      parameter (LLm0=65,   MMm0=48,   N=16)
#elif defined CANYON_B
      parameter (LLm0=66,   MMm0=48,   N=16)
#elif defined EQUATOR
      parameter (LLm0=40,   MMm0=32,   N=32)   ! 100 km resolution
#elif defined KH_INST
....
#  elif defined  BENGUELA_LR
      parameter (LLm0=41,   MMm0=42,
N=32)   ! BENGUELA_LR
#  elif defined  BENGUELA_HR
      parameter (LLm0=83,   MMm0=85,
N=32)   ! BENGUELA_HR
#  elif defined  BENGUELA_VHR
      parameter (LLm0=167,  MMm0=170,
N=32)   ! BENGUELA_VHR
#  elif defined MENOR
      parameter (LLm0=1059, MMm0=447,
N=40)   ! MENOR
#  elif defined SEINE
      parameter (LLm0=411,  MMm0=181,
N=20)   ! SEINE
#  else
      parameter (LLm0=94,   MMm0=81,
N=40)
#  endif
#else
      parameter (LLm0=xx, MMm0=xx, N=xx)
#endif
...
!
...
```

Configuring the model

Domain decomposition for parallelization : param.h

```
!
!----------------------------------------------------------------------
! MPI related variables
!----------------------------------------------------------------------
!
     integer Lmmpi,Mmmpi,iminmpi,imaxmpi,jminmpi,jmaxmpi
     common /comm_setup_mpi1/ Lmmpi,Mmmpi
     common /comm_setup_mpi2/ iminmpi,imaxmpi,jminmpi,jmaxmpi
!
! 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;
!
     integer NSUB_X, NSUB_E, NPP
```

```
#ifdef MPI
     integer NP_XI, NP_ETA, NNODES
     parameter (NP_XI=1,  NP_ETA=2,
NNODES=NP_XI*NP_ETA)
     parameter (NPP=1)
     parameter (NSUB_X=1, NSUB_E=1)
#elif defined OPENMP
     parameter (NPP=4)
# ifdef AUTOTILING
     common/distrib/NSUB_X, NSUB_E
# else
     parameter (NSUB_X=1, NSUB_E=NPP)
# endif
#else
     parameter (NPP=1)
# ifdef AUTOTILING
     common/distrib/NSUB_X, NSUB_E
# else
     parameter (NSUB_X=1, NSUB_E=NPP)
# endif
#endif
….
```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Values of variables for your configuration
jobcomp
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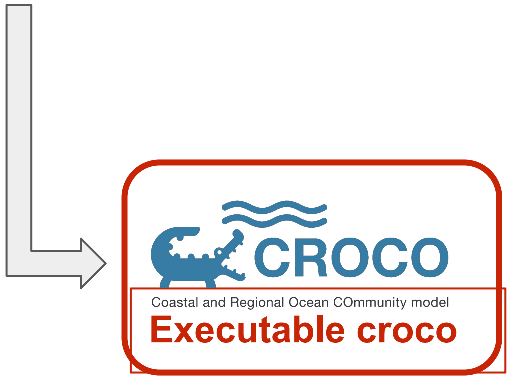
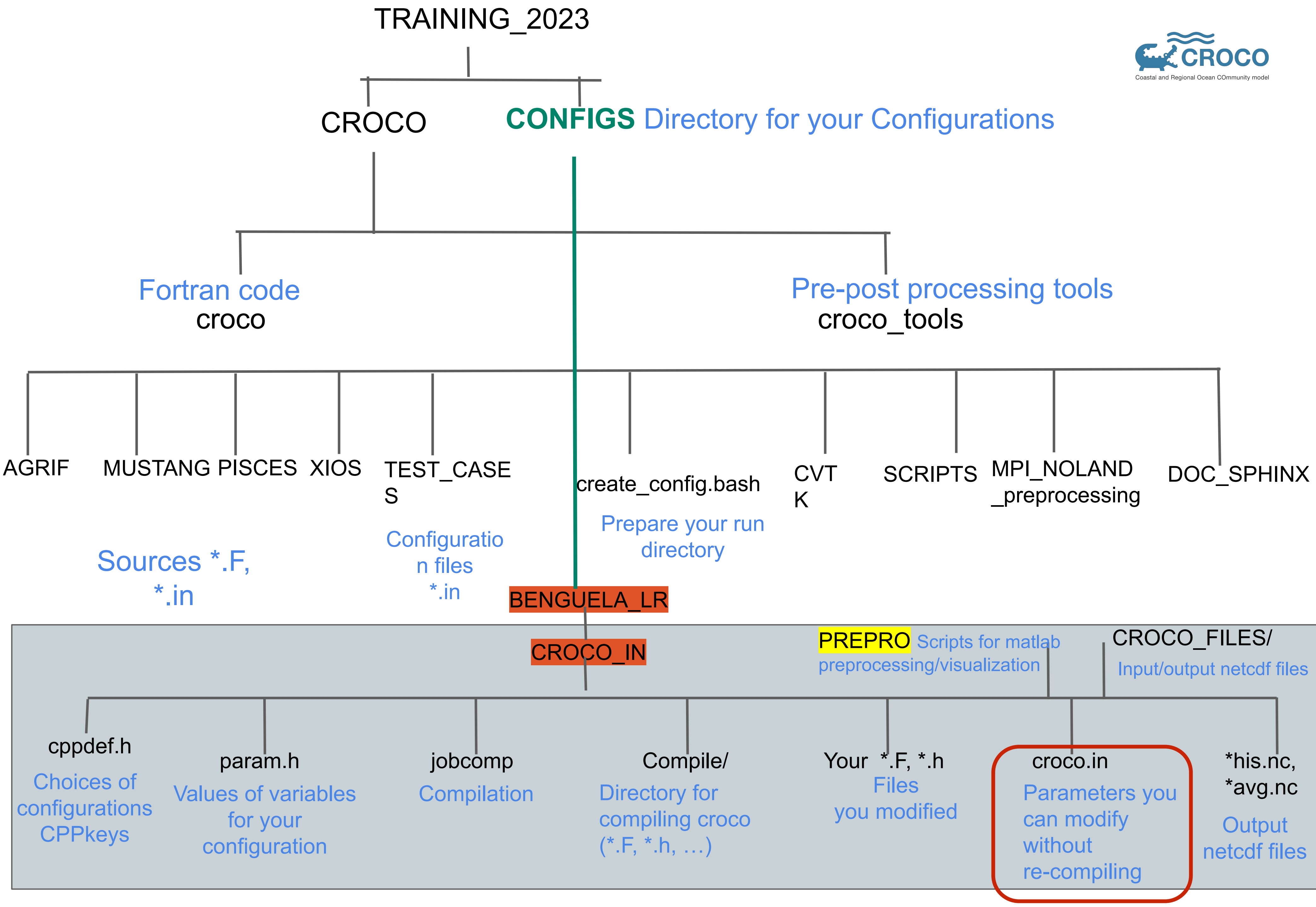
Compile/
Directory for compiling croco (*.F, *.h, …)
Your *.F, *.h Files you modified
croco.in
Parameters you can modify without re-compiling
*his.nc, *avg.nc
Output netcdf files

Compiling the model

cd $HOME/TRAINING_2023/CONFIGS/BENGUELA_LR/CROCO_IN

./jobcomp.bash





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CROCO_FILES/
Input/output netcdf files
cppdef.h
Choices of configurations CPPkeys
param.h
Values of variables for your configuration
jobcomp
Compilation
Compile/
Directory for compiling croco (*.F, *.h, …)
Your *.F, *.h Files you modified
croco.in
Parameters you can modify without re-compiling
*his.nc, *avg.nc
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CROCO
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Input file croco.in

Copy an example of croco.in suitable for Regional configuration:

cd /home/userX/TRAINING_2023
cd CONFIGS/BENGUELA_LR/CROCO_IN
cp ~/TRAINING_2023/CROCO/croco/OCEAN/croco.in .

```
grid:  filename
    ../CROCO_FILES/croco_grd.nc
forcing: filename
    ../CROCO_FILES/croco_frc.nc
bulk_forcing: filename
    ../CROCO_FILES/croco_blk.nc
climatology: filename
    ../CROCO_FILES/croco_clm.nc
boundary: filename
    ../CROCO_FILES/croco_bry.nc
initial: NRREC / filename
          1
    ../CROCO_FILES/croco_ini.nc
restart:          NRST, NRPFRST / filename
                   720    -1
    ../CROCO_FILES/croco_rst.nc

history: LDEFHIS, NWRT, NRPFHIS / filename
            T      72     0
    ../CROCO_FILES/croco_his.nc
averages: NTSAVG, NAVG, NRPFAVG / filename
            1      72     0
    ../CROCO_FILES/croco_avg.nc
```

change CROCO_FILES to ../CROCOFILES everywhere

Input file croco.in

CROCO Coastal and Regional Ocean COmmunity model

Documentation :
https://croco-ocean.gitlabpages.inria.fr/croco_doc/tutos/tutos.08.compil.html

```
title:
    BENGUELA TEST MODEL
time_stepping: NTIMES   dt[sec]  NDTFAST  NINFO
          8640     1200      60      1
time_stepping_nbq: NDTNBQ   CSOUND_NBQ   VISC2_NBQ
              1       1000       0.01
S-coord: THETA_S,   THETA_B,    Hc (m)
        7.0d0     2.0d0      200.0d0
run_start_date:
01/04/2014 00:00:00
run_end_date:
01/01/2016 00:00:00
output_time_steps: DT_HIS(H), DT_AVG(H), DT_RST(H)
             1      6       12
grid:  filename
   CROCO_FILES/croco_grd.nc
forcing: filename
   CROCO_FILES/croco_frc.nc
bulk_forcing: filename
   CROCO_FILES/croco_blk.nc
climatology: filename
   CROCO_FILES/croco_clm.nc
boundary: filename
   CROCO_FILES/croco_bry.nc
initial: NRREC  filename
        1
   CROCO_FILES/croco_ini.nc
restart:         NRST, NRPFRST / filename
             2160    -1
   CROCO_FILES/croco_rst.nc
history: LDEFHIS, NWRT, NRPFHIS / filename
         T      72     0
   CROCO_FILES/croco_his.nc
averages: NTSAVG, NAVG, NRPFAVG / filename
         1      72     0
   CROCO_FILES/croco_avg.nc
```

same as in the crocotools_param.m

variables or diagnostics in output netcdf files

```
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 Visc3d Diff3d  HBL HBBL
Bostr Wstr Ustr Vstr Shfl Swfl rsw rlw lat sen  HEL
                     F   F    T   F    T    F    F     F     T   T    T     T    T    T    T    T   10*T
gls_history_fields:   TKE  GLS  Lscale
                 T     T    T

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  Visc3d Diff3d HBL HBBL Bostr
Wstr Ustr Vstr Shfl Swfl rsw rlw lat sen HEL
               F   T    T   F    T    F    F     F     T   T    T     T   T    T     T    T   10*T
gls_averages:  TKE  GLS  Lscale
             T     T    T
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]
               XXX              XXX

nudg_cof:    TauT_in, TauT_out, TauM_in, TauM_out  [days for all]
             1.      360.      3.      360.
```

mpirun -np 2 ./croco croco.in

```
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.
...
Activated C-preprocessing Options:
...
Spherical grid detected
hmin          hmax          grdmin          grdmax          Cu_min      Cu_max
 75.000000  4803.032721 .301836927E+05 .331215714E+05  0.12176008  0.91533005
 volume=9.5239860932610875000000E+14   open_cross=6.1048368883124446868 90E+09
...
MAIN: started time-steping.
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
...
```

Courant number:

evaluation of the CFL criterion: dx/dt > fastest waves (here gravity waves).

Cu_max < 1 !!!

Climatology simulation

1) Crocotools presentation for preprocessing

2) Climatology simulation (simulation with no restart)

3) Inter annual simulation

Running the model : Multi-months launching

In many studies, there is a need for long simulations : spin-up , statistical equilibrium.

For regional models, 10 years appears to be a reasonable model duration.

In this case, it is easier to do several simulations of 1 month, using restart at the end of each month to start the next month.

run_croco.bash for climatological forcing or **run_croco_inter.bash** for interannual forcing do it automatically

- It get the grid, the initial file and the boundary file
- In case of a interannual forcing, we have realistic forcing, segmented month by month, from various atmospheric/oceanic reanalysis [for example : croco_ini_SODA_Y2004M1.nc, croco_frc_CFSR_Y2004M1.nc or croco_bry_ECCO_Y2004M1.nc]
- It runs the model for 1 month
- It store the files in a specific for in the directory SCRATCH
    - For climatological forcing : roms_avg_Y4M3.nc (i.e march of year 4)
    - For interannual forcing : roms_avg_Y2004M3.nc (i.e march of year 2004)
- It replace the initial file by the restart file (croco_rst.nc) which has been generated at the end of the month.
- It relaunch the model for the next month

Multi-months simulations with climatological forcings

Documentation :
https://croco-ocean.gitlabpages.inria.fr/croco_doc/tutos/tutos.10.run.inter.html

11. Running with interannual forcing

11.1. Run after classical interannual pre-processing

Before running you should prepare your interannual inputs files following the Interannual Preprocessing tutorial.

To run a plurimonth simulation, we provide the following scripts in `~/croco/croco/SCRIPTS/Plurimonths_scripts`:

- `run_croco.bash`: Plurimonth run with climatological forcing

Documentation :
https://croco-ocean.gitlabpages.inria.fr/croco_doc/tutos/tutos.10.run.inter.html

11. Running with interannual forcing

11.1. Run after classical interannual pre-processing

Before running you should prepare your interannual inputs files following the Interannual Preprocessing tutorial.

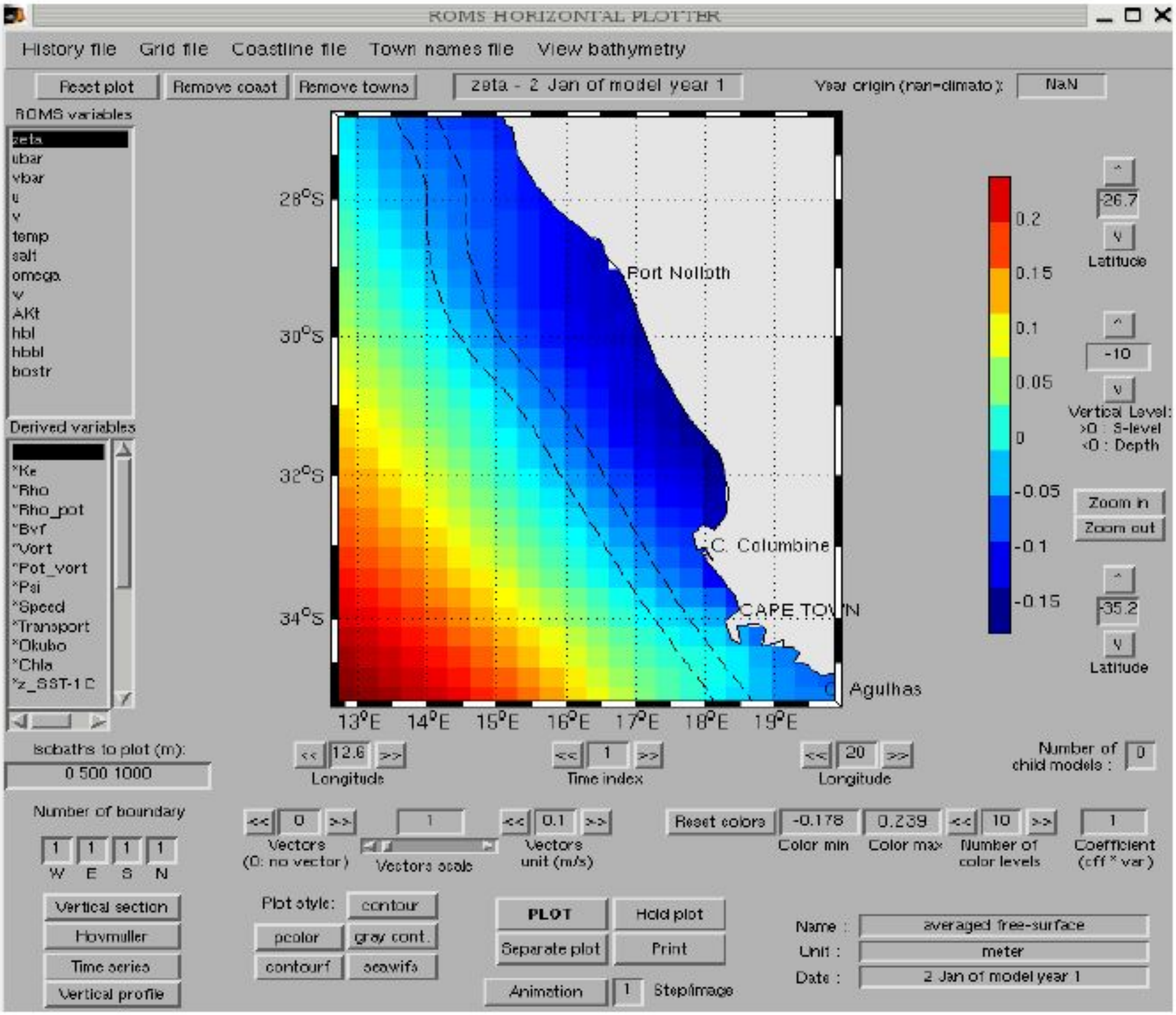
To run a plurimonth simulation, we provide the following scripts in `~/croco/croco/SCRIPTS/Plurimonths_scripts` :

- `run_croco_inter.bash` : Plurimonth run with interannual forcing

Visualization

Documentation :
https://croco-ocean.gitlabpages.inria.fr/croco_doc/tutos/tutos.14.visu.matlab.html

```
$matlab
>> croco_gui
```

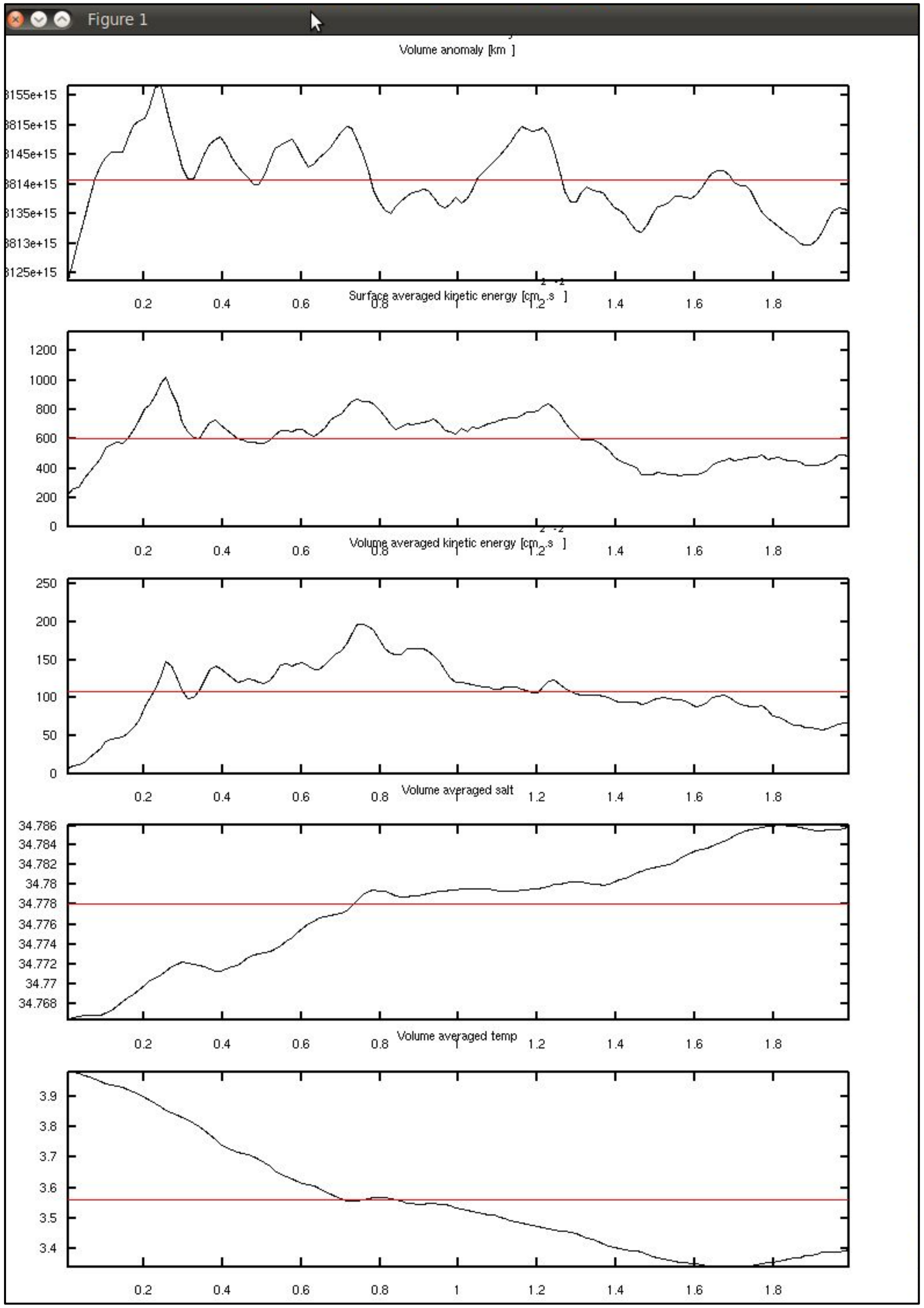


Global Diagnostics

CROCO
Coastal and Regional Ocean COmmunity model

Scripts for the simulation analysis in croco_tools/Diagnostics_tools

croco_diags	Get volume and surface averaged quantities
plot_diags	Plot averaged quantities
get_Mmean	Get monthly mean climatology
get_Smean	Get seasonal and annual mean climatology
get_Meddy	Get seasonal and annual variance climatology
get_Seddy	Get seasonal and annual variance climatology



Adding Tides

Documentation :
https://croco-ocean.gitlabpages.inria.fr/croco_doc/tutos/tutos.13.tides.html

The tides are imposed at open boundaries using the characteristic open boundary conditions (define **OBC_M2CHARACT** cpp-keys)

- ξ_{tides}, $\overline{u}_{tides}$, $\overline{u}_{tides}$: ssh and depth averaged zonal and meridian currents are added at the open boundaries
- ξ_{tides}, $\overline{u}_{tides}$, $\overline{u}_{tides}$ are computed from the tidal harmonics given by some tidal model, in our case TPXO9 (0.25° resolution, 10 tidal components : M2, N2,S2,K2, K1, 01,P1, Q1, Lm, Mm)

- The global tidal model gives harmonics constants for all the principal tidal waves. These constants permits to compute at every time t, $\xi^N_{tides}(t)$, $\overline{u}^N_{tides}(t), and\ \overline{u}^N_{tides}(t)$ of the tidal wave component N.

You need :

- Choose the number of tidal wave component you want
- Interpolate on the grid the different harmonic constants
- Possibility to add the generator potential

Adding Tides

```
matlab >> make_tides

Start date for nodal correction : 1-Jan-2000
Reading CROCO grid parameters ...
Tidal components : M2 S2 N2 K2 K1 O1 P1 Q1 Mf Mm
Processing tide : 1 of 10
 ssh...
Getting ssh_r for time index 1
Getting ssh_i for time index 1
 u...
Getting u_r for time index 1
Getting u_i for time index 1
 v...
Getting v_r for time index 1
Getting v_i for time index 1
Convert to tidal ellipse parameters...
Process equilibrium tidal potential...
Process tidal loading and self-attraction potential...
Get total tidal potential...
Processing tide : 2 of 10
 ssh...
Getting ssh_r for time index 2
Getting ssh_i for time index 2
 u...
Getting u_r for time index 2
Getting u_i for time index 2
 v...
Getting v_r for time index 2
Getting v_i for time index 2
Convert to tidal ellipse parameters...
Process equilibrium tidal potential...
Process tidal loading and self-attraction potential...
Get total tidal potential…
```

The tidal forcings are added in the croco_frc.nc file.

To define the tides, in cppdefs.h

```
# ifdef TIDES
#  define SSH_TIDES
#  define UV_TIDES
#  define POT_TIDES
#  undef  TIDES_MAS
#  ifndef UV_TIDES
#   define OBC_REDUCED_PHYSICS
#  endif
#  define TIDERAMP
# endif
```

Adding Tides

Tidal forcing parameter & temporal parameters

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
% 5 - Parameters for tidal forcing
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
% TPXO file name (TPXO6 or TPXO7)
%
tidename=[DATADIR,'TPXO7/TPXO7.nc'];
%
% Self-Attraction and Loading GOT99.2 file name
%
sal_tides=1;
salname=[DATADIR,'GOT99.2/GOT99_SAL.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;   % Example:
lat0 = -33.91;   % Cape Town location
Z0   =  1;       % Mean depth of tide gauge
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

For real time runs, with tides forcing , a procedure correct phases and amplitudes (nodal corrections) (Egbert and Erofeeva (2002))

Adding a biogeochemical forcing

In CROCO , several biogeochemical model : 1D vertical equation (subroutine biology.F)

- Nitrogen -based model of increasing complexity:
  - **NPZD**
  - **N2PZDD2**
  - **BIOBUS**
- Not only Nitrogen-based (including Iron, etc..): **PISCES**

For initial and lateral boundary condition :

- Seasonal climatology of nitrate provided from WOA (2005 or 2009)
- Seasonal climatology of surface chlorophyll provided from SeasWifs

Adding a biological forcings

Choose the BGC model you want (section Applications in cppdefs.h)

```
# define BIOLOGY
...
 /*   Choice of Biology models   */
# ifdef BIOLOGY
#  undef  PISCES
#  undef BIO_NChlPZD
#  undef  BIO_N2ChlPZD2
#  define BIO_BioEBUS
                     /*   Biology options    */
#  ifdef PISCES
#   undef  DIURNAL_INPUT_SRFLX
#   define key_pisces
#  endif
#  ifdef BIO_NChlPZD
#   define  OXYGEN
#  endif
#  ifdef BIO_BioEBUS
#   define NITROUS_OXIDE
#  endif
```

Adding a biological forcings

croco_tools :

- make_biol : for climatology file
- make_bry_npzd :
  _bioebus :
  _pisces : for boundary files

```
> make_biol
Add_no3: creating variables
and attributes for the OA file
write no3time
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

 ….
```

crocotools_param.m

```
%
% Pisces biogeochemical seasonal climatology
%
woapisces_dir = [DATADIR,'WOAPISCES/'];  % only
compatible with woa_dir
%
% Surface chlorophyll seasonal climatology (SeaWifs)
%
chla_dir=[DATADIR,'SeaWifs/'];
%
```

Adding a river forcing

Documentation :
https://croco-ocean.gitlabpages.inria.fr/croco_doc/tutos/tutos.12.rivers.html

Section Applications in cppdefs.h

```
/* Point Sources - Rivers */
# undef PSOURCE
# define PSOURCE_NCFILE
# ifdef PSOURCE_NCFILE
#   define PSOURCE_NCFILE_TS
# endif
```

Adding a river forcing

crocotools_param.m

```
%
% Runoff monthly seasonal climatology (Dai and Trenberth)
%
global_clim_riverdir=[DATADIR,'RUNOFF_DAI/'];
global_clim_rivername=[global_clim_riverdir,'Dai_Trenberth_runoff_global_clim.nc'];
%
%  Set times and cycles for the boundary conditions:
%   monthly climatology
%%
%   Set times and cycles for runoff conditions:
%   monthly climatology
%
qbar_time=[15:30:365];
qbar_cycle=360;
%
%   Tracer runoff concentration processing flag
%     pource_ts = 1  => Runoff tracers concentration processing is activated.
%                    It needs the climatology file created with make_clim.m
%     psource_ts = 0 => No Runoff tracers concentration processing
%                    It reads analytical values in croco.in
%                    or use default value defined in analytical.F
%
psource_ts=0;
%
```

Adding a river forcing

croco_tools : **make_runoff.m**

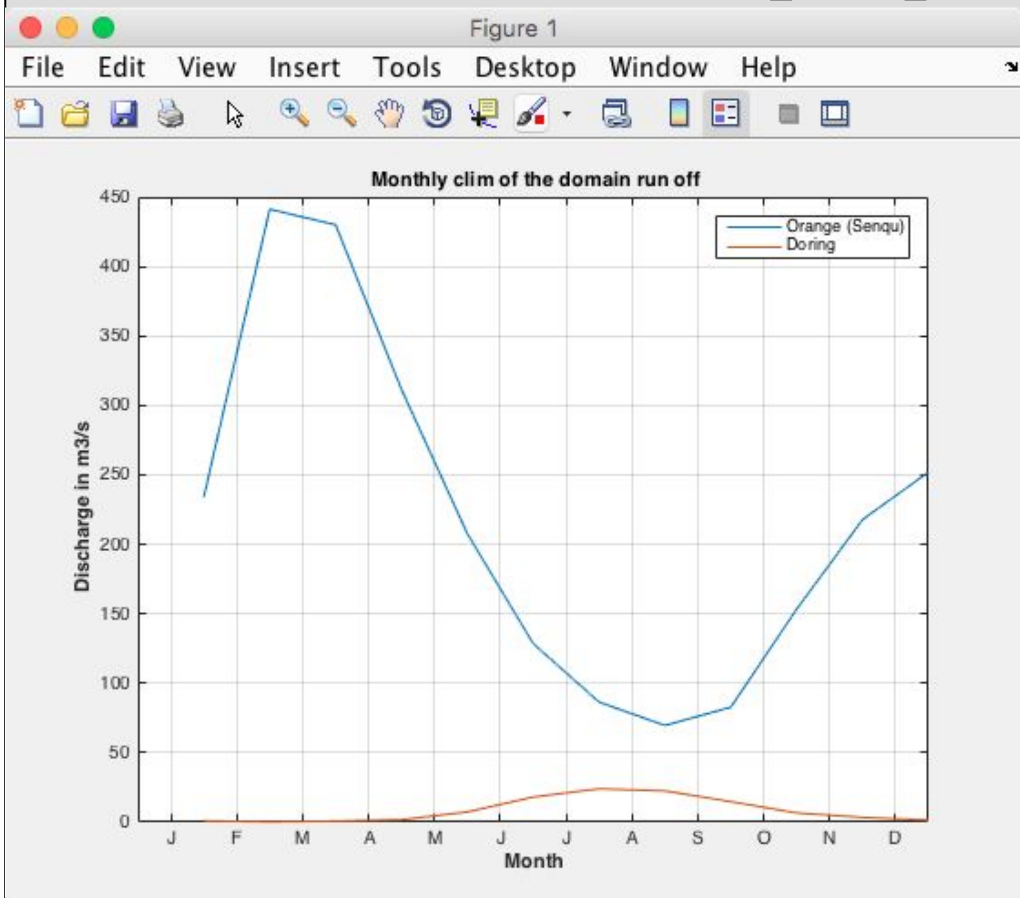
```
•  > In make_runoff (line 29)
•  mkdir: /Users/gcambon/DATA/for_asi18_sess2/CONFIGS/BENGUELA_LR/CROCO_FILES/: File
   exists

•  Create runoff forcing from Dai and Trenberth's global monthly climatological
   run-off dataset



•  Reading the global monthly climatological run-off dataset...

•  There are 2 rivers in the domain :
•  Domain contains rivers :
•  1 - Orange (Senqu)                  flowing in ocean ATL
•  2 - Doring                          flowing in ocean ATL

•  First guess:
•  ============

•  - Process river #1: Orange (Senqu)
•    Position is approximetly  J=35 and I=26
•  lon src in grid (rho point) ~16.3333
•  lat src in grid (rho point) ~-28.5604

•  - Process river #2: Doring
•    Position is approximetly  J=20 and I=35
•  lon src in grid (rho point) ~19.3333
•  lat src in grid (rho point) ~-32.8514
•  Do you want to use river (Yes[1], No[0]) ?  Orange (Senqu)
```

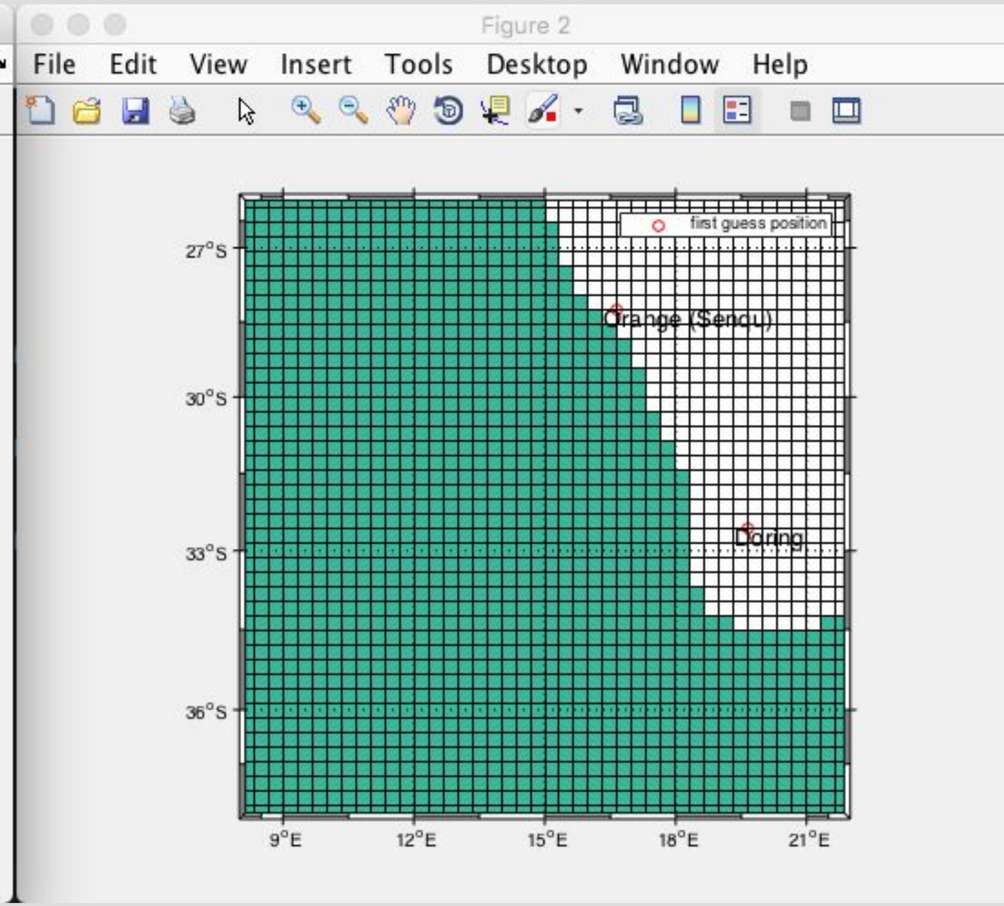
Adding a river forcing

CROCO
Coastal and Regional Ocean COmmunity model

croco_tools : **make_runoff.m**

- \> In make_runoff (line 29)
- mkdir: /Users/gcambon/DATA/for_asi18_sess2/CONFIGS/BENGUELA_LR/CROCO_FILES/: File

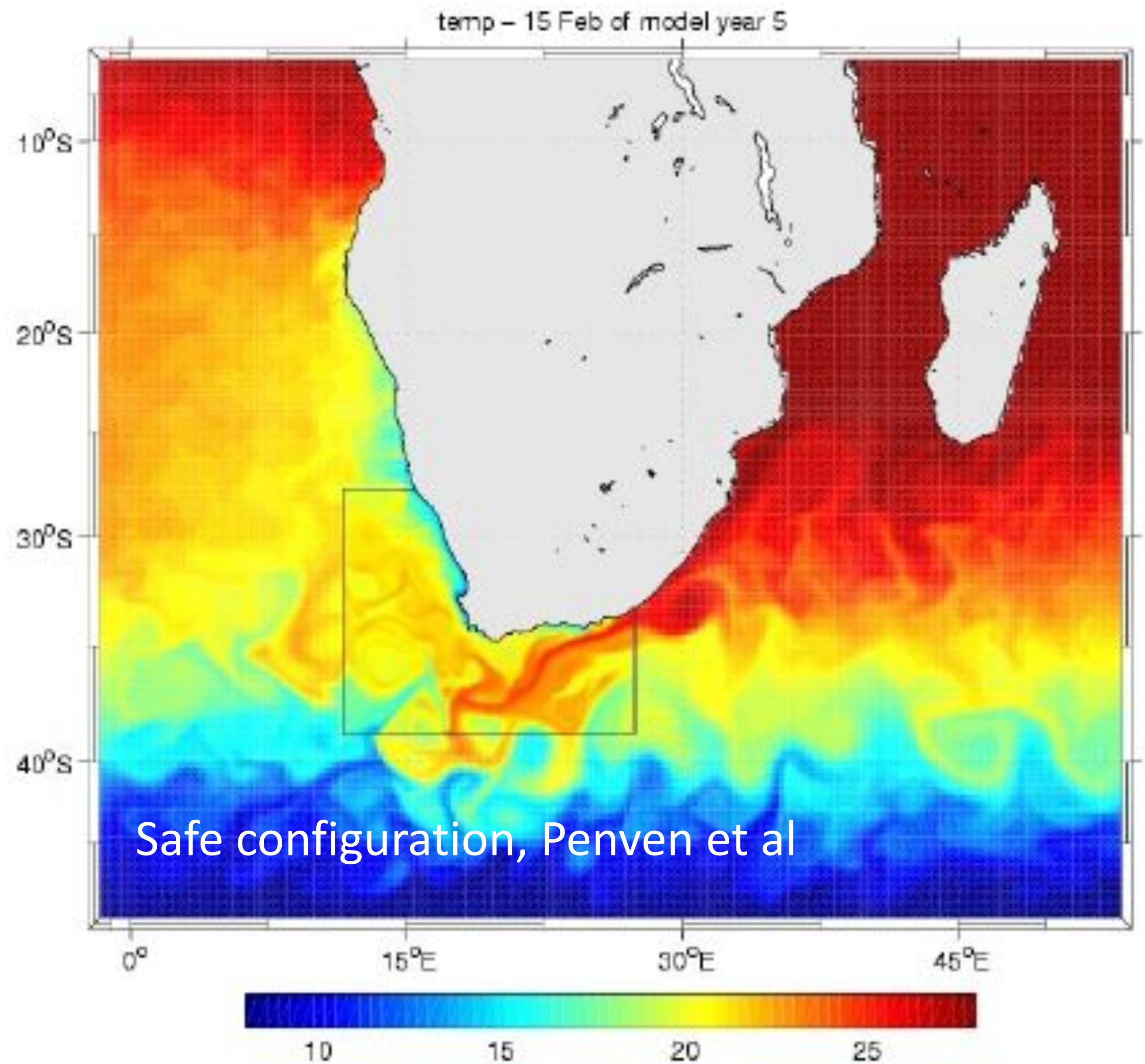




- \- Process river #2: Doring
- Position is approximetly J=20 and I=35
- lon src in grid (rho point) ~19.3333
- lat src in grid (rho point) ~-32.8514
- Do you want to use river (Yes[1], No[0]) ? Orange (Senqu)

Documentation :
https://croco-ocean.gitlabpages.inria.fr/croco_doc/tutos/tutos.11.nesting.html

Example :



AGRIF online nesting

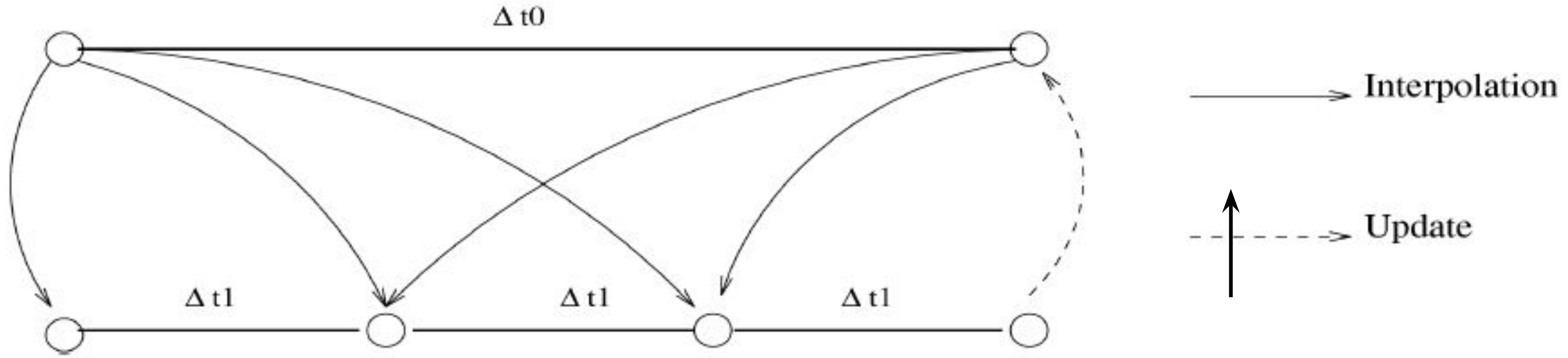
Nesting capability added to ROMS

→ AGRIF package

→ Adaptive Mesh Refinement

→ Manage arbitrary number of fixed grid and embedding level

Temporal coupling between a parent and a child grid for a refinement factor of 3 :



Needs to run an embedded model : Surface forcing and initial conditions datas files.

AGRIF names the different datas files as :

Parent file names : XXX.nc → First child file names : XXX.nc.1
second child file names : XXX.nc.2
. . .

Adding an AGRIF nest (online nesting)

With matlab

In the benguela test case, for the parent grid file, select in the entrance window of NestGUI and click 'open '

Follow the steps :

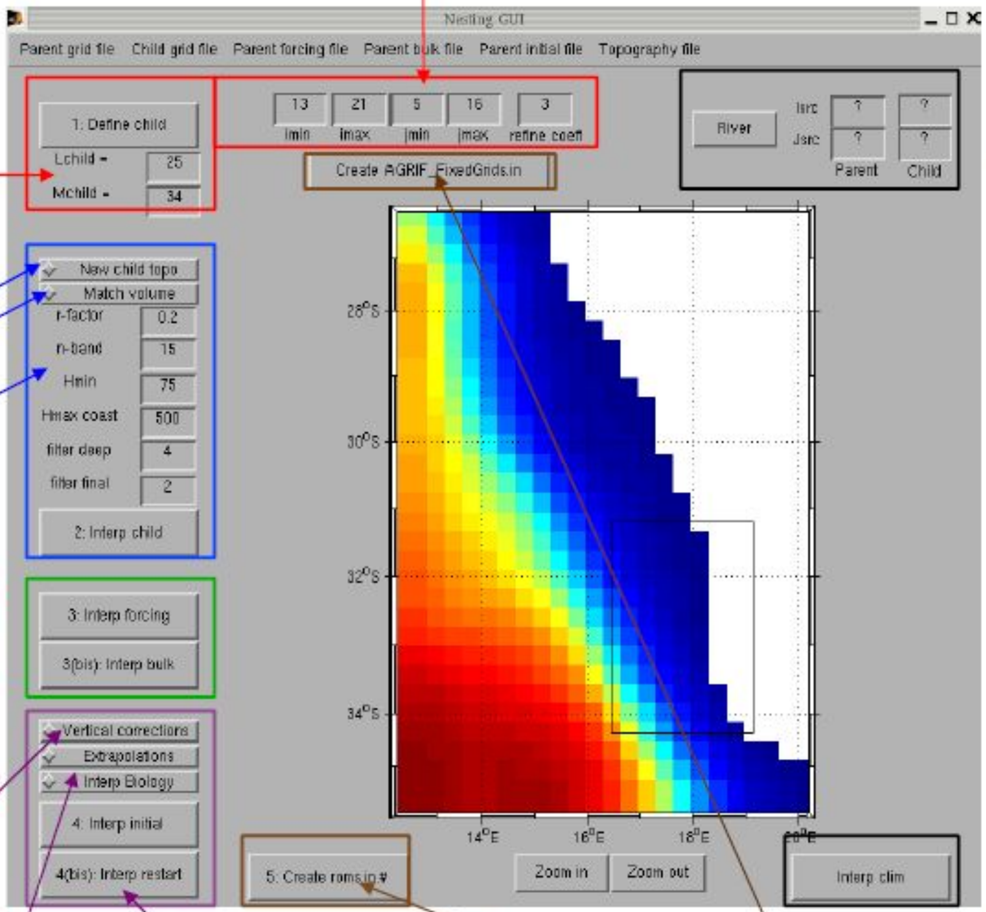
1- Tune the child domain

1- Define the child domain :
Size of the child grid

2- Create the child grid file :
What topography file?
Child grid volume
Parameters to change
-->

3- Create the surface forcing file:
Select _ _
--> roms_frc.nc.*. or roms_blk.nc.*.

4- Create the initial condition file:
Select roms_ini.nc
If different topography
Interpolate parent biological variables
--> roms_ini.nc.*.



Locate river on the coast

4- Select roms_rst.nc
--> roms_rst.nc.*.

5- Generate roms.in.*.
Create AGRIF_fixedGrids.in

Generate boundary condition to test the child model alone

Adding an AGRIF nest (online nesting)

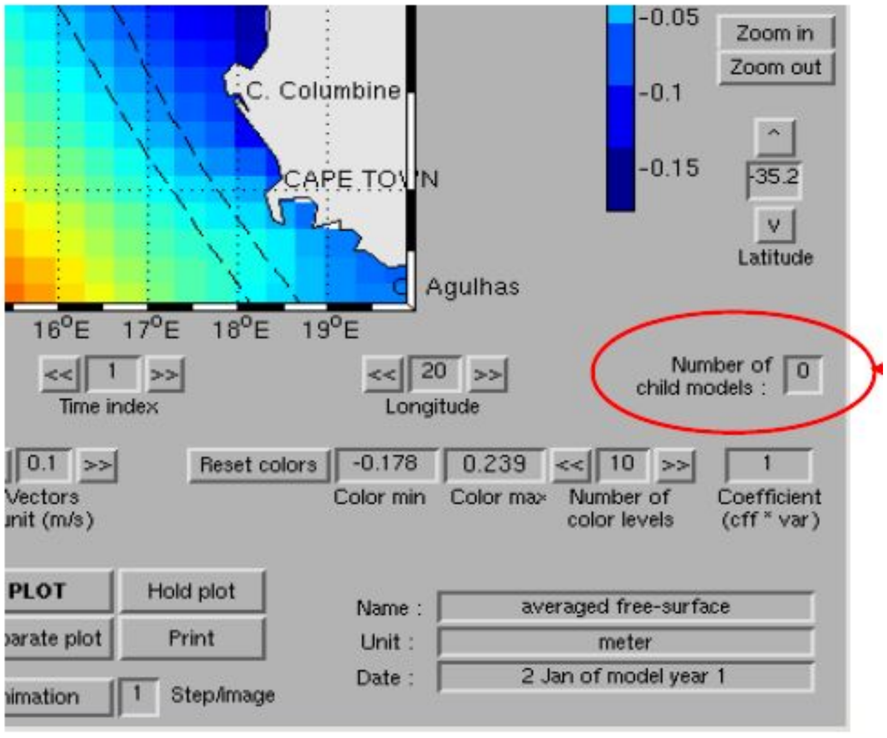
- To run a simulation with nesting, define the CPP keys and compile (./jobcomp)
  - AGRIF
  - AGRIF_2W

- Position of the different grid in AGRIF_FixedGrids.in file

```
  1
  23   37   12   29   3   3   3   3
  0
# number of children per parent
# imin imax jmin jmax spacerefx spacerefy timerefx timerefy
# [all coordinates are relative to each parent grid!]
```

- Namelist relative to the different nest level croco.in.1, croco.in.2 etc …

- Visualization (in Matlab) :
  - >>matlab
  - >>croco_gui



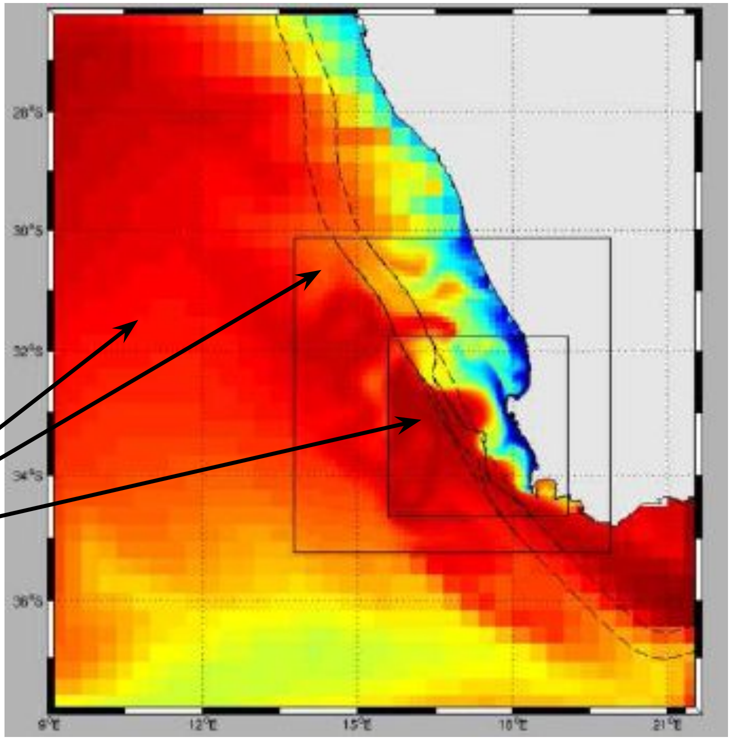
Adding an AGRIF nest (online nesting)

The file <u>Agrif_FixedGrids.in</u> define the position of the nested grid

```
 1
  23   37   12   29    3    3    3    3
  0
# number of children per parent
# imin imax jmin jmax spacerefx spacerefy timerefx timerefy
# [all coordinates are relative to each parent grid!]
```

2 grids : #0 and #1
#1 is embedded in #0

```
 1
  23   37   12   29    3    3    3    3
  1
  12   28   15   33    3    3    3    3
  0
# number of children per parent
# imin imax jmin jmax spacerefx spacerefy timerefx timerefy
# [all coordinates are relative to each parent grid!]
```



3 grids : #0,#1 and #2
#1 embedded in #0 ;
#2 is embedded in the #1

Needs to run an embedded model :

Surface forcing and initial conditions datas files.

<u>For grid #xx :</u>

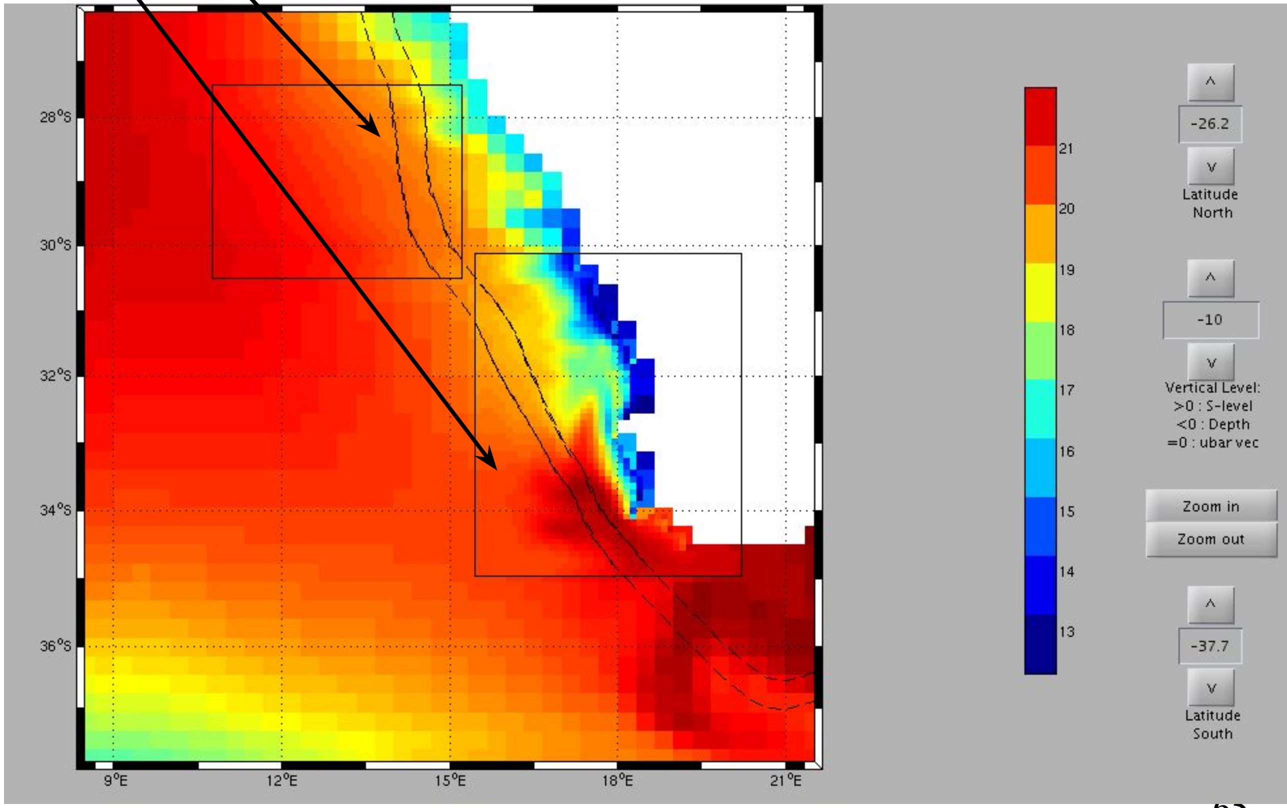
- croco_grd.nc.xx
- croco_frc.nc.xx
- croco_blk.nc.xx
- croco.ini.nc.xx
- croco.in.xx

Adding an AGRIF nest (online nesting)

```
   2
   23   37   12   29   3   3   3   3
   9    22   28   38   3   3   3   3
   0
   0
#number of children per parent
# …
```

3 grids : #0,#1 and #2

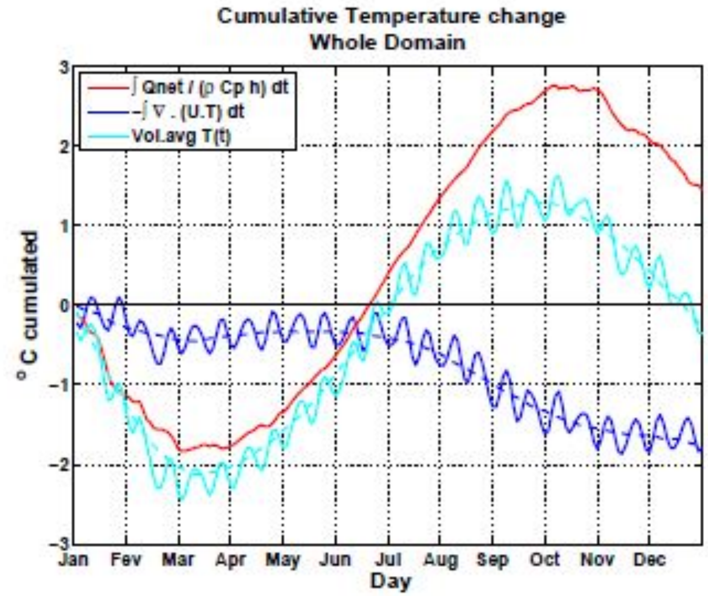
- #1 embedded in #0 ;
- #2 is embedded in #0 : independent grids

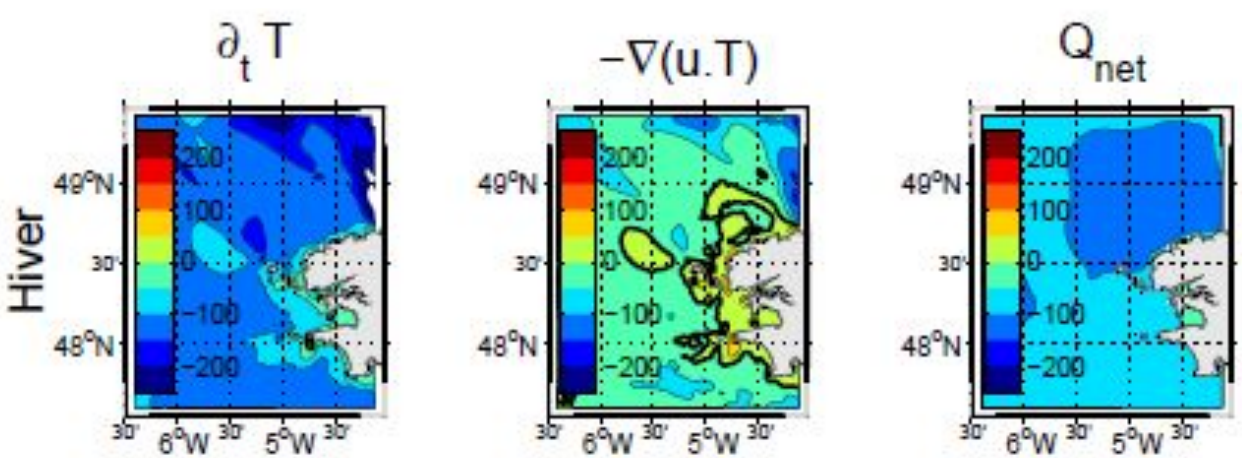


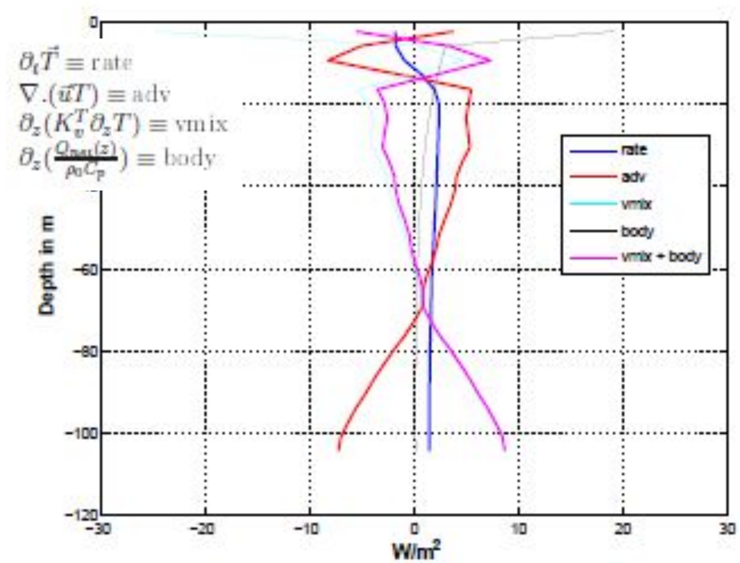
Online Diagnostics : Tracer equations terms

$$\partial_t T + \nabla.(\vec{u}T) = F^T + D^T$$
$$= K_h^T \Delta T + \partial_z\left(K_v^T \partial_z T\right) + \frac{1}{\rho_0 C_p}\partial_z\left(Q_{net}(z)\right)$$

- $\partial_t \vec{T}$: = Time rate (rate)
- $\nabla.(\vec{u}\mathbf{T})$: = Advection (adv)
- $\partial_z\left(K_v^T \partial_z T\right)$: Vert. mixing (vmix)
- $K_h^T \triangle \vec{T}$: Hori. mixing (hmix)
- $\partial_z\left(\frac{Q_{net}(z)}{\rho_0 C_p}\right)$ Solar heating forcing (body)







Online Diagnostics

Getting the terms of the equations, stored in netCDF files

- Momentum equation terms : define CPP keys DIAGNOSTICS_TS
- Tracer equation terms : define CPP keys DIAGNOSTICS_UV
- Biological fluxes terms : define CPP keys DIAGNOSTICS_BIO

In croco.in :

```
diagnostics:   ldefdia   nwrtdia    nrpfdia /filename
               T       72        0
                                 CROCO_FILES/croco_dia.nc
diag_avg: ldefdia_avg  ntsdia_avg  nwrtdia_avg  nprfdia_avg /filename
            T        1          72          0
                                 CROCO_FILES/croco_dia_avg.nc
diag3D_history_fields:    diag_tracers3D(1:NT)
                          30*T
diag2D_history_fields:    diag_tracers2D(1:NT)
                          30*T
diag3D_average_fields:    diag_tracers3D_avg(1:NT)
                          30*T
diag2D_average_fields:    diag_tracers2D_avg(1:NT)
                          30*T
```

```
diagnosticsM:   ldefdiaM   nwrtdiaM    nrpfdiaM /filename
                T        72        0
                                 CROCO_FILES/croco_diaM.nc
diagM_avg: ldefdiaM_avg  ntsdiaM_avg  nwrtdiaM_avg  nprfdiaM_avg
/filename
            T        1         72          0
                                 CROCO_FILES/croco_diaM_avg.nc
diagM_history_fields: diag_momentum(1:2)
                          T T
diagM_average_fields: diag_momentum_avg(1:2)
                                 T T
diagnostics_bio:   ldefdiabio   nwrtdiabio    nrpfdiabio /filename
                     T        72          0
                                 CROCO_FILES/croco_diabio.nc
diagbio_avg: ldefdiabio_avg  ntsdiabio_avg  nwrtdiabio_avg
nprfdiabio_avg /filename
                T          1          72          0
                                 CROCO_FILES/croco_diabio_avg.nc
```

Online Diagnostics : Tracer equations terms

Some precisions on advection

$\nabla.(\vec{u}T)$

$$u\partial_x T \neq \partial_x(u.T)$$

only

$$\partial_x(uT) + \partial_y(v.T) + \partial_z(w.T) = u\partial_x T + v\partial_y T + w\partial_z u$$

CPPKEYS: DIAGNOSTICS_TS

Storage:

- croco_diaM.nc and croco_diaM_avg.nc files.

- Can choose in croco.in the writing frequency and the terms to store

- By default : the different momentum terms with advection terms in "flux forms" :

$$T_{xadv} = \partial_x(u.T)$$

- With cppkey DIAGNOSTICS_TS_ADV : compute the "advective" forms :

$$T_{xadv-II} = u.\partial_x(T)$$

- with cppkey DIAGNOSTICS_TS_MLD : integration of the differents terms over the mixed layer HBL, computed by the KPP model

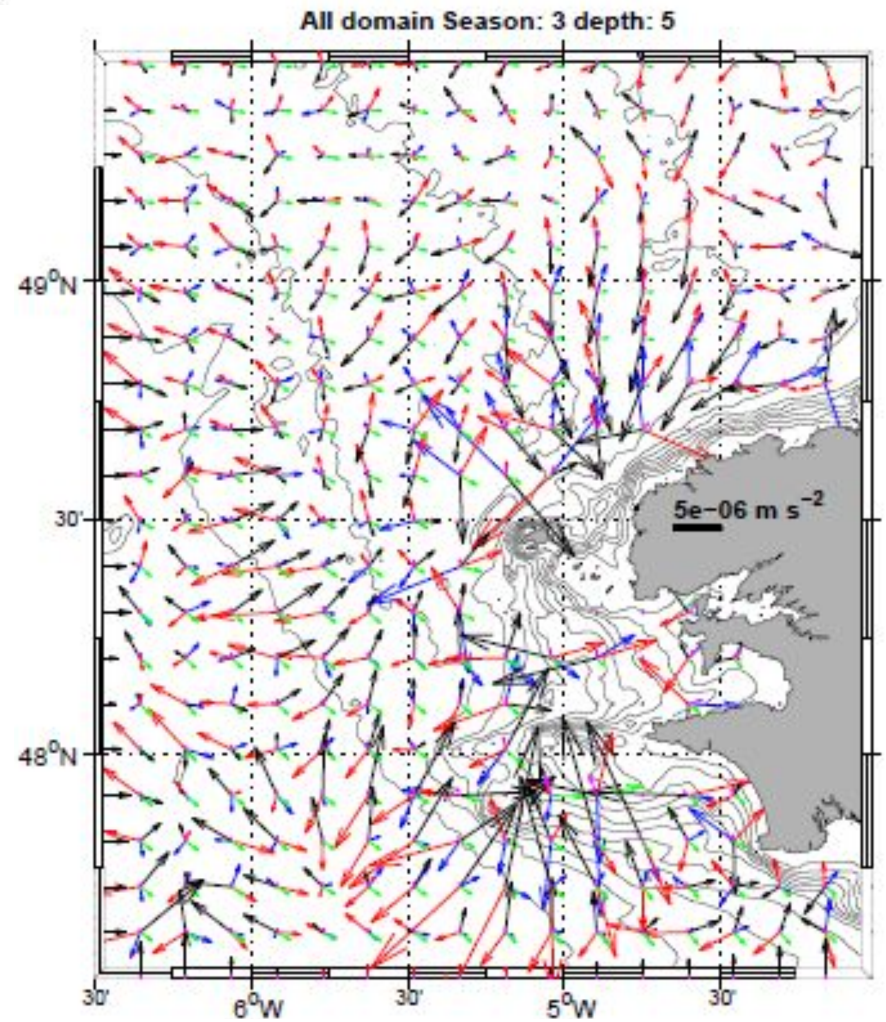
Online Diagnostics : Momentum equations terms

CROCO
Coastal and Regional Ocean COmmunity model

$$\frac{\partial u}{\partial t} + \vec{v}\cdot\nabla u - fv = -\frac{\partial \phi}{\partial x} - \frac{\partial}{\partial z}\left(\overline{u'w'} - \nu\frac{\partial u}{\partial z}\right) + \mathcal{F}_u + \mathcal{D}_u$$

$$\frac{\partial v}{\partial t} + \vec{v}\cdot\nabla v + fu = -\frac{\partial \phi}{\partial y} - \frac{\partial}{\partial z}\left(\overline{v'w'} - \nu\frac{\partial v}{\partial z}\right) + \mathcal{F}_v + \mathcal{D}_v$$

- Rate change term : $\partial_t \vec{u}$
- Coriolis term : $\begin{pmatrix} -fv \\ +fu \end{pmatrix}$
- Advection term : $\vec{u}.\nabla\vec{u}$
- Pressure gradient term : $-\nabla P/\rho_0.$
- Vertical mixing term : $\partial_z\left(K_v \partial_z \vec{u}\right)$
- Horizontal mixing term : $K_H \Delta \vec{u}$



Termes d'accélérations en $m.s^{-2}$:
Advection : $\vec{u}.\nabla\vec{u}$
Coriolis : $f\vec{u}$
Mélange vertical : $\partial_z\left(K_v\partial_z\vec{u}\right)$
Gradient de pression : $-\partial P/\rho_0$
Tendance temporelle : $\partial_t\vec{u}$

Online Diagnostics : Momentum equations terms

$$\vec{u}.\nabla\vec{u} \equiv \begin{pmatrix} u\partial_x u + v\partial_y u + w\partial_z u \\ u\partial_x v + v\partial_y v + w\partial_z v \end{pmatrix} = \begin{pmatrix} \partial_x(u.u) + \partial_y(u.v) + \partial_z(u.w) \\ \partial_x(u.v) + \partial_y(v.v) + \partial_z(v.w) \end{pmatrix}$$

$$= \begin{pmatrix} u_{xadv} + u_{yadv} + u_{vadv} \\ v_{xadv} + v_{yadv} + v_{vadv} \end{pmatrix}$$

Formulation flux

BUT take care :

$$u\partial_x u \neq \partial_x(u.u)$$

only

$$\left(\partial_x(u.u) + \partial_y(u.v) + \partial_z(u.w)\right) = \left(u\partial_x u + v\partial_y u + w\partial_z u\right)$$

CPPKEYS: DIAGNOSTICS_UV