Tutorial 03 LiveCROCO: Climatological Simulation

1. Purpose

In this tutorial we will review how to perform a climatology of Benguela domain in LiveCROCO virtual machine, the important files for this type of simulation, and its validation.

2. Creating working directory CLIMATOLOGIA

The simplest example of CROCO is the configuration named BENGUELA_LR which corresponds to a low resolution Benguela Upwelling Zone domain. This is the default configuration in CROCO code and what we will do is similar to what is described in Penven et al. (2001)

It is highly recommended to test new options of CROCO code in this domain before trying it in a domain that is more complex or takes much longer in computation time. We will assume that you already have a local copy of CROCO and CROCO_TOOLS code in your root directory. This can be achieved by following the steps in Tutorial 01.

The first step is to open a terminal by clicking on red icon on the left, under Firefox symbol, and in that terminal type

```
cd Desktop
```

and then edit **create_run.bash** file with instructions to create a new working directory that we will call **CLIMATOLOGIA**

```
nano create_run.bash
```

and modify configuration name,

```
#
# Name of the configuration directory defined by the user
#
MY_CONFIG_NAME='CLIMATOLOGIA'
#
```

The search paths for **CROCO_DIR**, **SOURCES_DIR**, and y **TOOLS_DIR** variables are predefined and should be correct.

Then run the statement

```
./create_run.bash
```

3. Input files

The input files that **croco** executable will read will be created with **CROCO_TOOLS**. It mainly depends on two files, **oct_start.m** and **crocotools_param.m**

3.1. oct_start.m

This file defines search paths for functions that will be used by CROCO_TOOLS.

3.2. crocotools_param.m

This file is very important because here we define study region and dimensions of input files, which must be compatible with those previously defined in **param.h**.

We will change the following line

```
%
makeplot     = 0;          % 1: create graphics after each preprocessing step
%
```

a

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

to see some graphs of input files that are created.

3.3. Using Octave

To create input files using Octave, the instructions to use, from **CLIMATOLOGIA** working directory are

```
octave-cli
```

In Octave the instructions to use, from work directory **CLIMATOLOGIA** are:
First we define search paths of tools used by CROCO_TOOLS

```
oct_start
```

Then we write the instruction to generate model grid, which is described in **croco_grd.nc** file that will be generated in **CROCO_FILES** directory

```
>> make_grid
mkdir: cannot create directory ‘/home/livecroco/Desktop/CLIMATOLOGIA/CROCO_FILES/’:
File exists

 Making the grid: /home/livecroco/Desktop/CLIMATOLOGIA/CROCO_FILES/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]
```

we press **n** and then it appears

```
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

Filter topography ...
Apply a filter on the Deep Ocean to reduce isolated seamounts :
  4 pass of a selective filter.
Apply a selective filter on log(h) to reduce grad(h)/h :
  20 iterations - r_max = 0.27931
  29 iterations - r_max = 0.24975
Smooth the topography a last time to prevent 2DX noise:
  2 pass of a hanning smoother.

Write it down...
```

and we get the figure

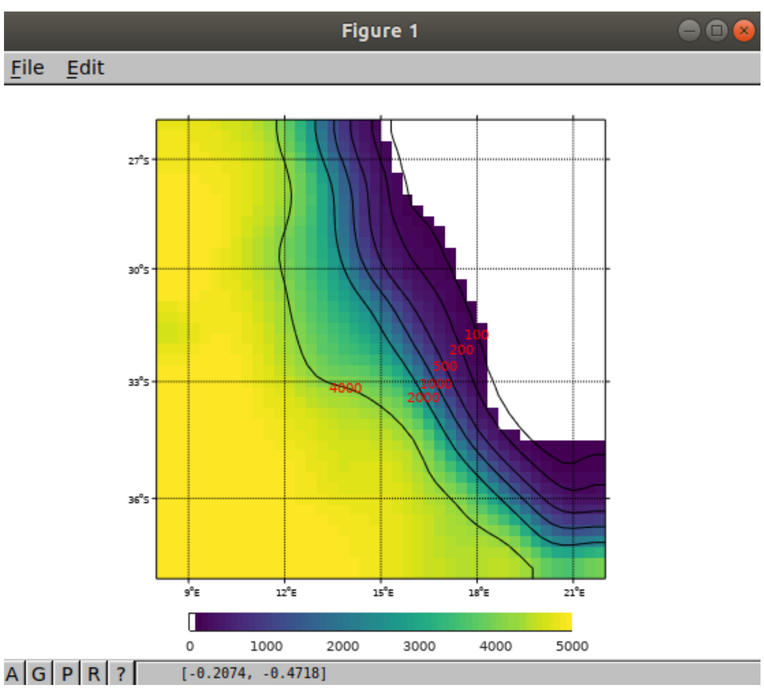

Figura 1: Final map of Benguela domain

When working in Octave, its call to **easygrid** and **editmask** functions, whose code does work in Matlab, is omitted.

The next instruction is **make_forcing** which creates **croco_frc.nc** file with atmospheric forcing information.

```
>> make_forcing
```

gives us 7 figures, Figs. 2-5

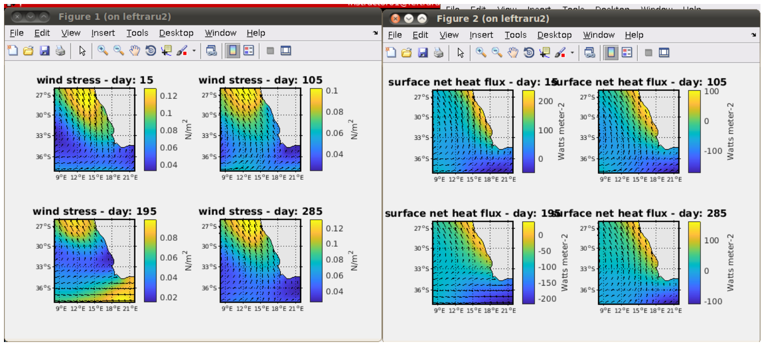

Figura 2: Atmospheric forcing variables: surface wind stress and net surface heat flux

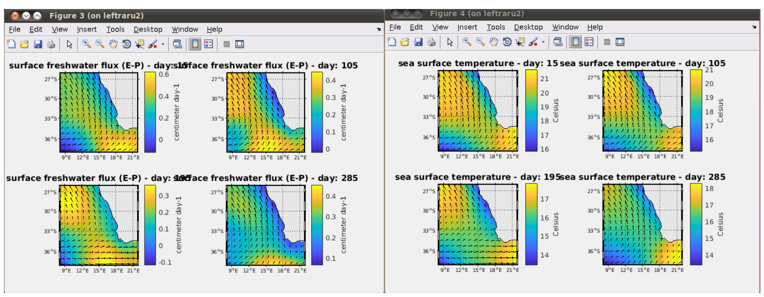

Figura 3: Atmospheric forcing variables: fresh water surface balance (E-P) and sea surface temperature

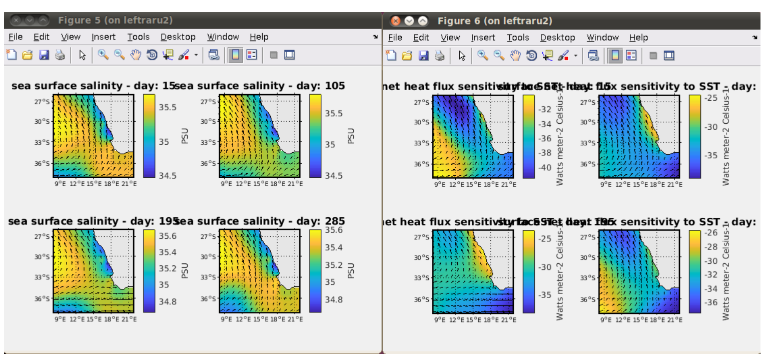

Figura 4: Atmospheric forcing variables: sea surface salinity and sea surface temperature sensitivity of latent heat flux

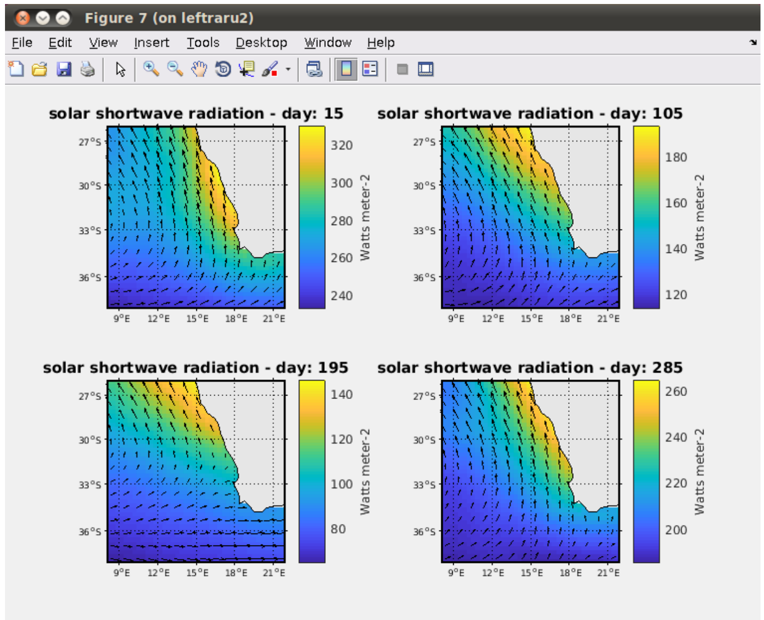

Figura 5: Atmospheric forcing variables: shortwave solar radiation.

And finally **make_clim** instruction that creates **croco_clm.nc** file with ocean boundary condition

```
make_clim
```

give us 8 figures, figs. 6-9

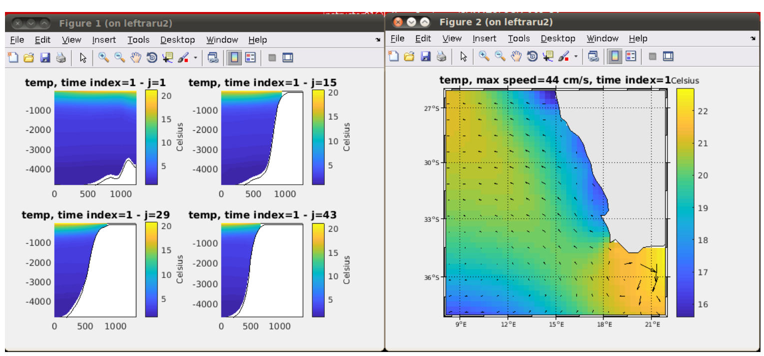

Figura 6: Oceanic lateral forcing variables: vertical sections and surface temperature at t = 1.

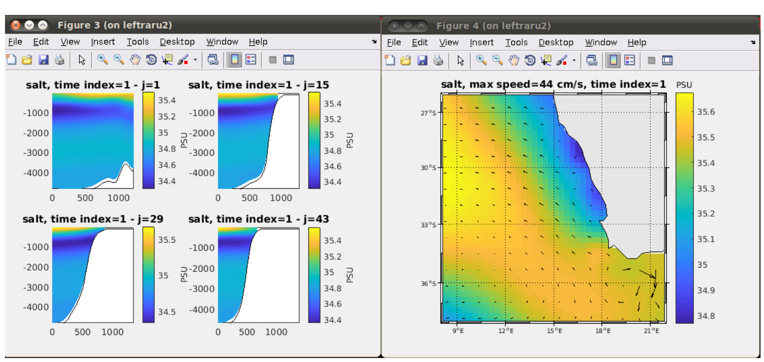

Figura 7: Oceanic lateral forcing variables: vertical sections and surface salinity at t = 1.

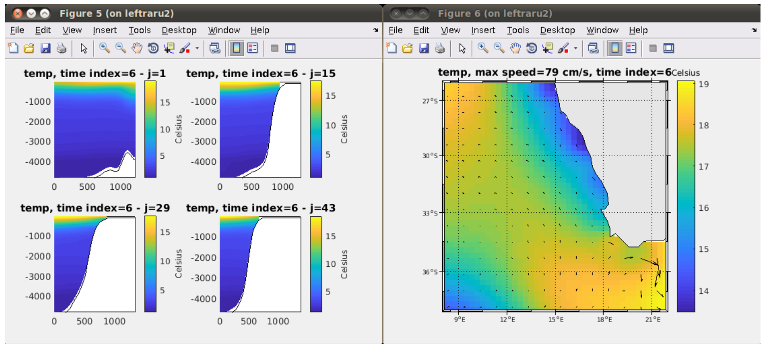

Figura 8: Oceanic lateral forcing variables: vertical sections and surface temperature at t = 6.

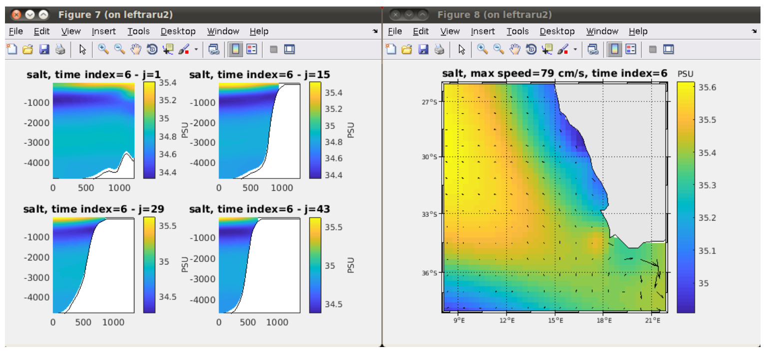

Figura 9: Oceanic lateral forcing variables: vertical sections and surface salinity at t = 6.

Note that this command also involves creating initial conditions (**croco_ini.nc** file), which can be created independently using **make_ini** command.

It is important that we first call **make_forcing** function and then **make_clim**. These instructions will create input files, in NetCDF format. These files will be inside CROCO_FILES directory. Shown here

```
croco_clm.nc croco_frc.nc croco_grd.nc croco_ini.nc croco_oa.nc
```

The files you get should be the same as those found in

```
http://mosa.dgeo.udec.cl/LiveCROCO/Tutorial03/ArchivosIniciales/
```

if you had problems with this step, copy those files to **CROCO_FILES** directory to proceed to next section using the instructions

4. How to make a climatology

To calculate a climatology, we have to force model over several years with the same oceanic and atmospheric boundary conditions, year after year. In this exercise we will do several simulations, each one of one year period. For this we will modify **croco.in** so that the number of time steps is 8640

```
time_stepping: NTIMES   dt[sec]  NDTFAST  NINFO
               8640     3600     60       1
```

Once this is done, we compile the model

```
./jobcomp
```

and run the simulation

```
./croco croco.in
```

Once simulation finishes successfully, we will find in **CROCO_FILES** directory the following output files

```
croco_avg.nc
croco_his.nc
croco_rst.nc
```

The **croco_rst.nc** file has information to continue the simulation, so to calculate next year we have to copy this file with name **croco_ini.nc**, which is the file that CROCO reads as initial condition.

```
cp croco_rst.nc croco_ini.nc
```

If we launch simulation again, HIS and AVG files will be needed, so we need to change the name before calculating the 2nd year.

```
cp croco_avg.nc croco_avg_Y1.nc
cp croco_his.nc croco_his_Y1.nc
cp croco_rst.nc croco_rst_Y1.nc
```

and now if we can calculate the 2nd year. To make a good climatology you have to calculate between 10 and 20 years, so you have to repeat this process many times. If your *BASH FU* is strong, you can automate this process in a script.

For purpose of this course, we will analyze only 10 years. Remember that the first years of a simulation are not reliable, they are part of what is known as *spin up*.

The CROCO code includes a routine that performs this process of running simulation, renaming and continuing automatically, it is file called **run_croco.bash**.

5. Climatology validation

To analyze the climatology it is convenient to separate annual files into monthly files. For this we will use **separa_meses.bash** script that includes **NCO** routines that you can copy from next window.

```
#!/bin/bash

#
# Andrés Sepúlveda 12/2020 (DGEO-UDEC)
#

#
# It is assumed that the file as a record every three days
#
export model=croco
export type=avg

yi=1
yf=2

while [ "$yi" -le "$yf" ]
do
        ncks -F -d time,1,10      "$model"_"$type"_Y"$yi".nc "$model"_"$type"_Y"$yi"M1.nc
        ncks -F -d time,11,20     "$model"_"$type"_Y"$yi".nc "$model"_"$type"_Y"$yi"M2.nc
        ncks -F -d time,21,30     "$model"_"$type"_Y"$yi".nc "$model"_"$type"_Y"$yi"M3.nc
        ncks -F -d time,31,40     "$model"_"$type"_Y"$yi".nc "$model"_"$type"_Y"$yi"M4.nc
        ncks -F -d time,41,50     "$model"_"$type"_Y"$yi".nc "$model"_"$type"_Y"$yi"M5.nc
        ncks -F -d time,51,60     "$model"_"$type"_Y"$yi".nc "$model"_"$type"_Y"$yi"M6.nc
        ncks -F -d time,61,70     "$model"_"$type"_Y"$yi".nc "$model"_"$type"_Y"$yi"M7.nc
        ncks -F -d time,71,80     "$model"_"$type"_Y"$yi".nc "$model"_"$type"_Y"$yi"M8.nc
        ncks -F -d time,81,90     "$model"_"$type"_Y"$yi".nc "$model"_"$type"_Y"$yi"M9.nc
        ncks -F -d time,91,100    "$model"_"$type"_Y"$yi".nc "$model"_"$type"_Y"$yi"M10.nc
        ncks -F -d time,101,110   "$model"_"$type"_Y"$yi".nc "$model"_"$type"_Y"$yi"M11.nc
        ncks -F -d time,111,120   "$model"_"$type"_Y"$yi".nc "$model"_"$type"_Y"$yi"M12.nc
        yi=`expr $yi + 1`
done
exit
```

```
./separa_meses.bash
```

This will give us files like

```
croco_avg_Y1M1.nc
croco_avg_Y1M2.nc
croco_avg_Y1M3.nc
croco_avg_Y1M4.nc
...
```

Then open Octave and use routines

1. croco_diags.m
2. plot_diags.m

that are part of CROCO_TOOLS for analysis.

5.1. Calculation of monthly climatologies

Once we have monthly files we can use script

```
http://mosa.dgeo.udec.cl/LiveCROCO/Tutorial03/script_make_clim.v2.bash
```

to average all months of each simulated year and thus obtain its own monthly climatology.

5.2. Expected results

you should be able to generate

1. Domain map
2. The time series plots generated by **plot_diags.m** function
3. Surface temperature maps for seasonal averages and annual average.

5.3. Climatology validation

The global sea surface temperature archive measured between 1985 and 1997 with AVHRR-Pathfinder sensor (Casey and Cornillon, 1999)

```
/home/livecroco/DataSets/SST_pathfinder/climato_pathfinder.nc

```

The values are monthly averages of sea surface temperature at a resolution of 9.28 km. Use this file and write a routine that allows you to get following:

1. SST Pathfinder data in seasonal and annual average for study region.
2. A map with difference between your results and the Pathfinder data.

Do the same for monthly climatology of sea surface salinity which you can get in the following file

```
http://mosa.dgeo.udec.cl/LiveCROCO/Tutorial03/SMAP_L3_SSS_MONTHLY_CLIM_V5.0.nc
```

6. Advanced Work

Run a simulation for a domain of interest.

7. Conclusion

In this tutorial you learned more details about **cppdefs.h**, **param.h**, and **croco.in** files, and modifications that must be made to make a climatological simulation, as well as aspects of validation of results .

For more information:
Andrés Sepúlveda (asepulveda@dgeo.udec.cl)
Contribuciones de:
Iván Almendra
Marcela Contreras
Mauro Santiago

If you found this tutorial useful, please send a postcard to:

```
Dr. Andrés Sepúlveda
Departamento de Geofísica
Casilla 160-C
Correo 3
Concepción
Chile
```

8. References

Casey, K. S., & Cornillon, P. (1999). A Comparison of Satellite and In Situ-Based Sea Surface Temperature Climatologies. J. Climate, 12, 1848-1863

Penven, P., Roy, C., Brundrit, G. B., De Verdière, A. C., Fréon, P., Johnson, A. S., Lutjeharms J. R. E. & Shillington, F. A. (2001). A regional hydrodynamic model of upwelling in the Southern Benguela. South African Journal of Science, 97(11-12), 472-475.

9. Helpful Links

- NCO tools

  http://research.jisao.washington.edu/data/nco/