COAWST configuration guide

Third Edition

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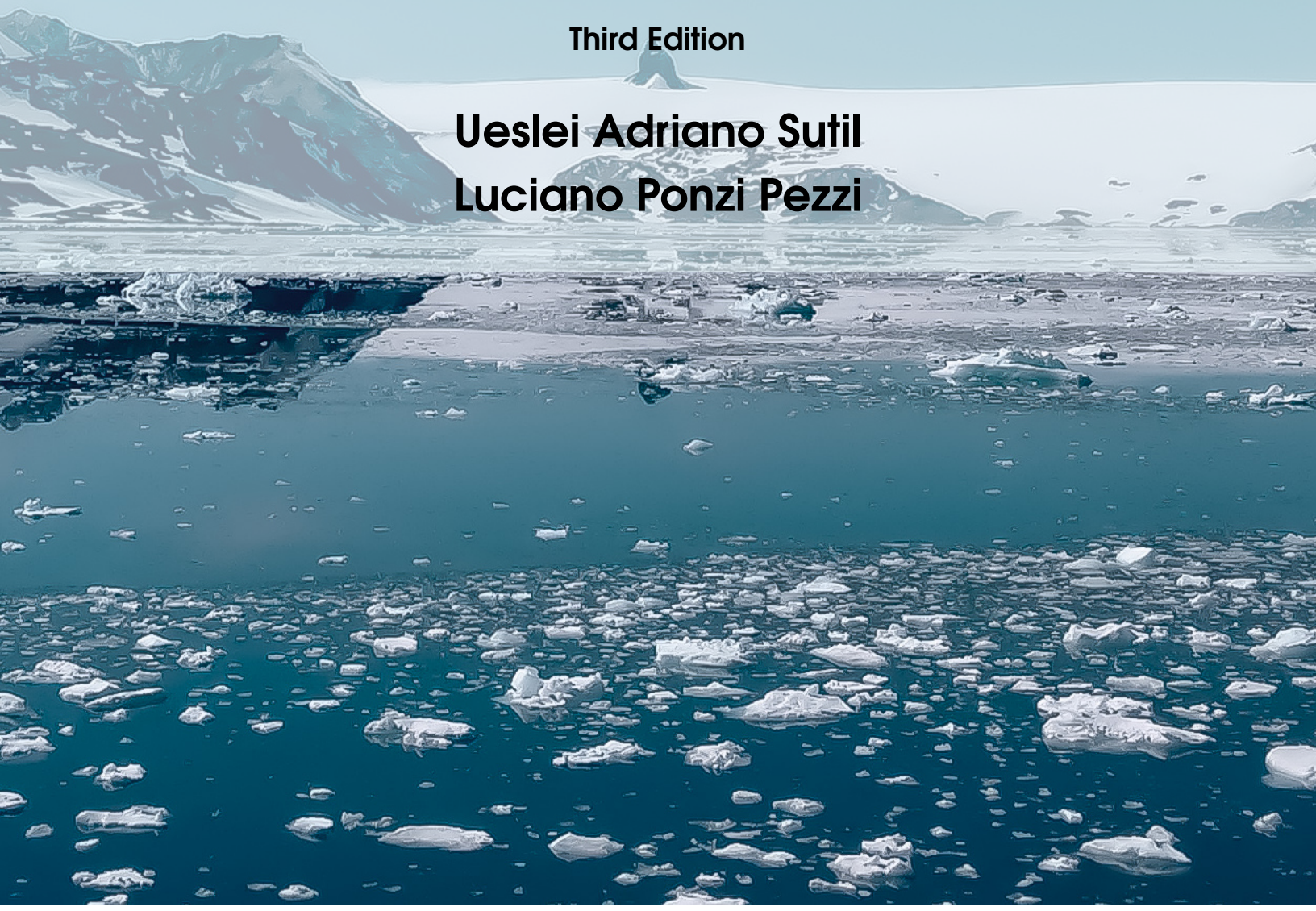

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The *model2roms* toolbox (https://github.com/trondkr/model2roms) was created by Trond Kristiansen (me@trondkristiansen.com) and is licensed under a *MIT License*.

Third edition
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Reviewers

The authors would like to thank the following peers for reviewing the **COAWST configuration Guide - First Edition** (in Portuguese):

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Thank you.

Author's note

This guide is designed to assist new users to use the Coupled Ocean-Atmosphere-Wave-Sediment Transport System (COAWST). The main idea behind this guide is to teach the necessary steps to use COAWST, beginning with its installation, then a simulation of a test case and the configuration of a project. To achieve this goal, we use several programming languages, such as Fortran, Python and MATLAB. In the future we intend to adapt all scripts to a free programming language.

When we started writing this guide, we wanted to pass on our experience of using a numerical modeling system that is considered the state of the art in our field, throughout reading, understanding how it works and how to use the COAWST, allying theory with practice.

However, a major difficulty in this process was the generation of the boundary and initial conditions of the oceanic model, the Regional Ocean Modeling System (ROMS), which rely on paid software. To get around this problem we chosed to work with the *model2roms* toolbox package. This set of routines was developed in Python and Fortran language by Trond Kristiansen (http://www.trondkristiansen.com).

We emphasize that in some chapters, the reader will find how to use the COAWST in a cluster that is available for use by the Ocean and Atmosphere Studies Laboratory (LOA) of the National Institute for Space Research (INPE). This is a system of high performance computing that allows parallel numerical operations. In this case, the guide may serve only as inspiration and the reader's prior knowledge in applying COAWST in his own cluster system will be worthwhile.

In this third edition, we highlight the update to COAWST v.3.6, a new chapter about how to compile the model in a computer without parallel architecture.

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We wish you a good reading and success in your research.

The authors.

Contents

1. Introduction

This guide provides a brief introduction to the models that make up the Coupled Ocean-Atmosphere-Wave-Sediment Transport Modeling System (COAWST), as well as the additional user settings required for specific projects. As shown in Figure 1.1, COAWST uses several models and programs that will be presented below:

- **COAWST**: Core of the coupled numerical modeling system. More information in the section 1.7;
- **ROMS**: The hydrodynamic model. More information in the Section 1.1;
- **Sea Ice**: The sea ice model, coupled to ROMS. In this guide we use the Budgell's Sea Ice Model. More information in the Section 1.2;
- **WRF**: The atmospheric model. More information in the Section 1.3;
- ***wrf***: Executable program to start the WRF atmospheric simulation. More information in the section 4.4;
- ***real***: Executable program to generate the initial condition and the boundary forces of the WRF. More information in the Section 4.3.5;
- ***WPS***: Package with three programs to generate the files to be used in *real*. More information in the Section 4.2;
- ***geogrid***: Program to, mainly, generate the WRF grid domain. More information in the section 4.3.1;
- ***ungrib***: Briefly, the program that extracts the data in *GRIB* format. More information in the Section 4.3.3;
- ***metgrid***: Briefly, the program that interpolates the data generated by *ungrib*. More information in the Section 4.3.4;
- **SWAN**: The wave model. More information in the Section 1.4;
- **MCT**: The set of codes that couples the previous models. More information in the Section 1.5;
- **SCRIP**: Package that interpolates and remaps the model's grids to allow the models to be coupled. More information in the section 1.6.

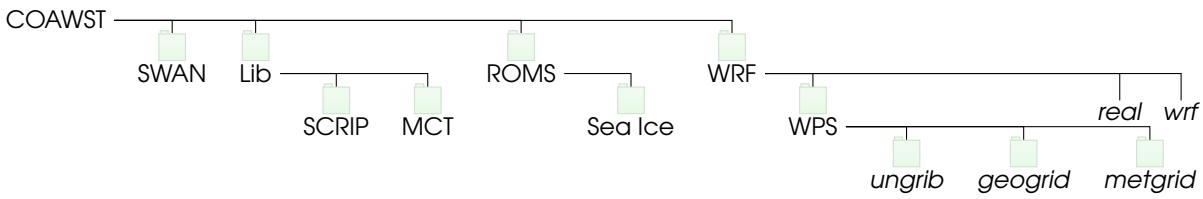

Figure 1.1. COAWST folder structure

When writing this guide, we chosed to use Python as a programming language for some steps. It is a programming language designed with a philosophy of emphasizing the importance of the programmer's effort over the computational effort and prioritizes code readability over speed or expressiveness. The language has a wide and active community, which facilitates the search information by the user, as there is an extensive collection of libraries and documents on the internet.

Python Brazil (*http://python.org.br*) offers great help for beginners, providing introductions about the language and also a guide to use Python for scienfic purposes.

We also use MATLAB as a language. It is a paid, but high-performance interactive software focused on the numerical calculation. The MATLAB Answers website is a platform created to offer help to the users about the language. The site is avaliable at https://www.mathworks.com/matlabcentral/answers/index,

1.1 Regional Ocean Modeling System

The Regional Ocean Modeling System (ROMS; Shchepetkin & McWilliams, 2005) is a three-dimensional ocean model with free surface, vertical sigma coordinate with sigma vertical coordinates (that follow the terrain) and solve primitive equations. The model uses the Reynolds average and the finite difference method to solve the Navier-Stokes equations using hydrostatic approximations and Boussinesq (cite Haidvogel2008).

The hydrostatic equations of momentum use a split-explicit time-step scheme, where the barotropic and baroclinic modes are solved separately, in different finite numbers of steps of time, to solve the free surface equations and it is integrated vertically. This structure separate time-steps frames maintains the volume conservation and consistency preservation that are necessary for the tracers (Haidvogel et al., 2008; Shchepetkin & McWilliams, 2005).

The model solves the horizontally equations through orthogonal curvilinear coordinates of the Arakawa-C grid type (Arakawa & Lamb, 1977). Vertically, the coordinates follow the features of the terrain and allow you to adjust the resolution along the water column. To guarantee the conservation of momentum, the grid uses econd order finite differences (Haidvogel et al., 2008).

ROMS is a model that has free code and its development has the contribution of the user community. Currently, the version used in COAWST is managed by Dr. Hernan Arango of Rutgers University. To access the model code, is necessary to register on the ROMS website (*https://www.myroms.org/*) The site has a extremely useful and very active forum to discuss about questions and suggestions. You can access here: (*https://www.myroms.org/forum*)

We recommend to read the ROMS Technical Manual, written by Hedström (2018). This manual has several information about the equations and algorithms of the model and examples of test cases.

1.2 Budgell's Sea Ice Model

The Sea Ice Model, proposed by Budgell (2005), has the same time and grid steps as the ROMS model and shares the same parallel encoding structure for use with Message Passing Import (MPI). Thus, allows dynamic and thermodynamic modeling where sea ice predominates, such as at high latitudes.

The main attributes of the model, according to Hedström (2018), are:

- Hunke & Dukowicz (1997) and Hunke (2001) elasctic-viscous-plastic dynamics;
- Mellor & Kanta (1989) thermodynamics;
- Orthogonal-curvilinear coordinates;
- Arakawa & Lamb (1977) grid;
- Smolarkiewicz & Grabowski (1990) advection of tracers;
- Lemieux et al. (2015) landfast ice parameterization.

1.3 Weather Research & Forecasting Model

The Weather Research and Forecasting (WRF; Skamarock et al., 2008) is a model developed by the National Centers for nvironmental Prediction (NCEP), the National Center for Atmospheric Research (NCAR) and research groups from different universities.

To integrate the governing equations over time, the Advanced Research WRF (ARW) uses low frequency modes that are integrated using the third-order Runge-Kutta scheme, and the integrated acoustic and gravity (high frequency) modes with a lower time step. By this way, the numerical stability is maintained through a "forward-backward" scheme for acoustic modes that propagate horizontally and an implicit scheme for acoustic modes for vertical propagation and buoyancy oscillations (Skamarock et al., 2008).

The WRF model uses an Arakawa-C type grid (Arakawa & Lamb, 1977), where normal speeds are staggered halfway through the grid of thermodynamic variables, as shown in the schematic representation illustrated in Figure 1.2.

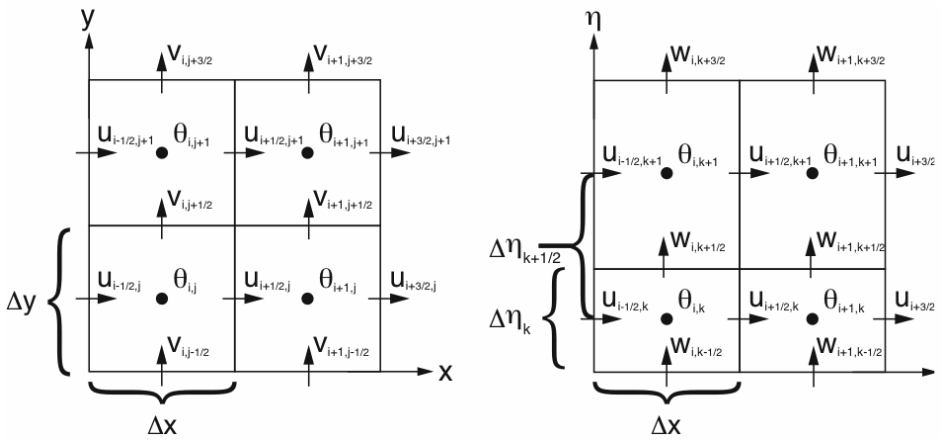

Figure 1.2. Horizontal and vertical grid of Weather Research and Forecast (WRF) using the Arawaka-C grid. The horizontal and vertical components of velocity (**u**, **v** and **w**) are positioned along the faces of the grids and the thermodynamic variables (θ) are positioned in the center of each grid.
Author: Skamarock et al. (2008).

It is important to note that the WRF, without coupling with other models, simulates the surface roughness based on the ratio of roughness to wind shear proposed by Charnock (1955), as exemplified in the following equation 1.1:

$$Z_0 = Z_{ch}\frac{u_*^2}{g} \tag{1.1}$$

Where Z_0 é a roughness, Z_{ch} is the Charnock parameter (a dimensionless value of 0,018), u_* the frictional speed (m/s) and g the gravity acceleration(9,81 m/s^2).

The WRF is avaliable at: *http://www2.mmm.ucar.edu/wrf/users/download/get_source.html*

1.4 Simulating Waves Nearshore

The Simulating Waves Nearshore (SWAN; Booij et al., 1996, 1999) is a third generation model, designed to simulate coastal regions with shallow waters and local currents. The model is widely used in the numerical forecast of the Simulating Waves Nearshore (SWAN; Booij et al., 1996, 1999) is a third generation model, designed to compute in coastal regions with shallow waters and local currents. The model is widely used in the numerical forecast of waves in coastal regions, estuaries, channels and others, being able to use fields of wind, bathymetry and currents provided by other models (Booij et al., 1996, 1999).

Silva (2013) and Booij et al. (1996; Booij et al., 1999) list the main characteristics of the SWAN:

- Wave propagation in time and space, shoaling, refraction due to current and depth, frequency shifting due to currents and non-stationary depth;
- Wave generation by wind;
- Whitecapping, bottom friction and depth-induced breaking;
- Dissipation due to aquatic vegetation, turbulent flow and viscous fluid mud;
- Wave-induced set-up;
- Propagation from laboratory up to global scales;
- Transmission through and reflection (specular and diffuse) against obstacles;
- Diffraction.

More features can be found in SWAN website, avaliable at: *http://swanmodel.sourceforge.net/*.

1.5 Model Coupling Toolkit

The Model Coupling Toolkip (MCT; Jacob et al., 2005; Larson et al., 2005; Warner et al., 2008) is a set of open-source scripts, written in Fortran90 that allow the transmission and transformation of the different data necessary for model coupling. During initialization, model domains are broken down into segments that are distributed between processors, allowing models to be coupled also in parallel.

According to the MCT website, (*http://www.mcs.anl.gov/research/projects/mct/*), the toolkit provides the following core coupling services:

- A component model registry;
- Domain decomposition descriptors;
- A time averaging and accumulation buffer datatype;
- A general spatial grid representation capable of supporting unstructured grids;
- Parallel tools for intergrid interpolation;
- Tools for merging data from multiple components for use by another component;
- A programming model similar to that of the Message Passing Interface.

1.6 Spherical Coordinate Remapping Interpolation Package

O Spherical Coordinate Remapping Interpolation Package (SCRIP; Jones, 1998, 1999) is freely available for download at *https://github.com/SCRIP-Project/SCRIP*. The package is distributed together with COAWST modeling system. This package is used for projects that use more than one model and with different grids (with different spatial resolutions). SCRIP will generate the interpolation weights that will be used to remap the data between the different grids of the different models.

In COAWST, SCRIP was modified to generate a single file (in NetCDF format) that contains the weights based in each model grid.

1.7 Coupled-Ocean-Atmosphere-Wave-Sediment Transport Modeling System

The COAWST Warner et al., 2010, 2008) uses the WRF as the atmospheric model, the ROMS as the hydrodynamic model, the SWAN as the wave model and the sediment transport model Community Sediment Transport Modeling Project (CSTM; Warner et al., 2008), each one coupled by the MCT (Warner et al., 2010, 2008). The frequency with which this information is exchanged between the different models is adjusted by the user.

The coupling between the models allows the different physical processes that occur in both oceanic and atmospheric environments to be identified and analyzed with greater accuracy when compared to simulations without active coupling.(Miller et al., 2018; Pullen et al., 2018).

> **WARNING** This guide does not use CSTM. In case you are interested, there is a study on the transfer of sediments during Hurricane Isabel (2003) by Warner et al. (2010).

As shown in Figure 1.3, the informations exchanged between models are:

- WRF -> ROMS: surface shear and liquid heat fluxes (calculated in ROMS from the components of latent and sensitive heat fluxes) shortwave and longwave radiation, atmospheric pressure, relative humidity, air temperature, clouds, precipitation and wind components ;
- ROMS -> WRF: sea surface temperature;
- SWAN -> ROMS: surface and bottom wave direction, height, length, period, energy dissipation and lower orbital speed;
- ROMS -> SWAN: bathymetry, surface elevation, height of the sea and average currents in depth;

- SWAN -> WRF: roughness of the sea surface (calculated in WRF from the significant wave height, length and period);
- WRF -> SWAN: wind at 10m.

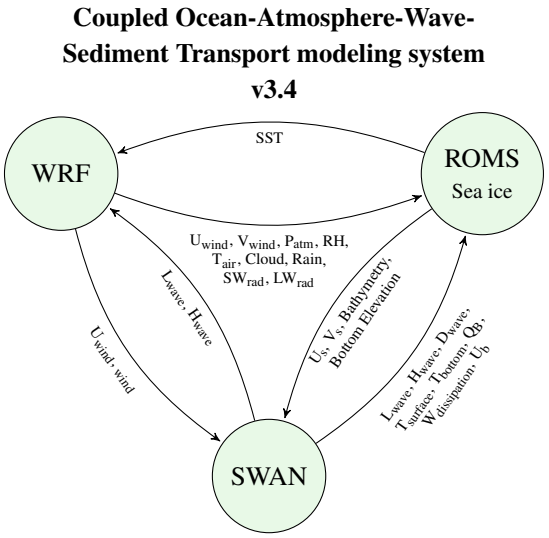

Figure 1.3. Diagram about the exchange of information between the main models that make up the COAWST modeling system. (Warner et al., 2008)

The Woods Hole Coastal and Marine Science Center page provides an experimental presentation on real time of COAWST (Sea Surface Temperature, Sea Surface Height, Significant Height Wave, Current and Wind Vectors and Sediment Dispersion) in the eastern United States and Gulf of Mexico. The content is available at: *https://woodshole.er.usgs.gov/project-pages/cccp/public/COAWST.htm*.

1.8 Materials needed to use this guide

To compile COAWST, this guide uses a cluster with parallel communication and a nonparallel Linux OS with Gfortran. If you choose to compile in on a computer with different specifications, use the original COAWST user manual as a reference, available in the modeling system repository. In this case, see how to download COAWST in the **??** section.

We will use Ubuntu 19.04 LTS. It is important to maintain the same systems operational, as other version may conflict with some libraries used by the *model2roms* toolkit or the COAWST itself.

WARNING This guide uses COAWST v. 3.6.

2. COAWST in a parallel cluster

2.1 About our cluster Kerana

The CRAY XE machine, also called Kerana, is a cluster with massively parallel architecture, with 84 processing nodes and 2688 cores and is located at CPTEC/INPE, in Cachoeira Paulista, São Paulo. For having the ability to parallelize operations through the MPI interface, the cluster is ideal for using numerical models with high spatial resolution and temporal.

> **WARNING** To compile COAWST on a computer without parallel communication, see chapter ??.

2.2 Signing up a user account

To start the process of applying for a user account in Kerana, it is necessary that the computer in the INPE's premises have a fixed IP. Your advisor or supervisor is required to send an email to *Helpdesk*(*helpdesk.cptec@inpe.br*) informing the MAC address, hostname and reason for the request. If the computer already has a fixed IP assigned, it also need to be informed to be changed.

With the fixed IP configured, contact the *Helpdesk*(*helpdesk.cptec@inpe.br*) to request a form to use Kerana.

2.3 Signing in to the Kerana cluster

Access will be done entirely through the computer terminal. You will need two primary commands: *ssh* for accessing and manipulating files and folders and *sftp* to download and upload files.

Para acessar e modificar arquivos e pastas, digite no terminal, substituindo *name.surname* pelo usuário fornecido pelo *Helpdesk*:

WARNING From now on, whenever the guide shows the user as *name.surname*, change to your username provided by the Helpdesk.

```
ssh -Y name.surname@acesso-hpc.cptec.inpe.br -p 2000
```

To do download and/or uploads, use:

```
sftp -P2000 name.surname@acesso-hpc.cptec.inpe.br
```

WARNING It is not possible to download and upload multiple files at the same time using *sftp*. One tip is to compress into a single *tar* file and then unzip them.

To add files from your computer to Kerana:

```
put file.tar.gz
```

To extract Kerana files to your computer:

```
get file.tar.gz
```

2.4 File repository

Certain files are needed in each user's area to facilitate the use of the cluster. You will find them in the directory:

```
/scratch/adriano.sutil/repositorio/
```

To copy the files to your area, type:

```
cp -r /scratch/adriano.sutil/repositorio /scratch/name.surname
```

WARNING From now on this guide will use the files that are inside this repository, so it is essential that they are in your area.

2.5 Kerana environment

It is necessary to activate some modules in the cluster to compile COAWST. In this case, open the file *.bashrc* which is located at the root directory of your user.

```
vim .bashrc
```

Add the following commands at the end of the file, changing only *name.surname* to your username:

```
module load java
module load netcdf

export PATH=/scratch/name.surname/repositorio/Softs/nedit/5.5:$PATH
export PATH=/scratch/name.surname/repositorio/Softs/bin:$PATH

export PHDF5=${HDF_DIR}
export WRFIO_NCD_LARGE_FILE_SUPPORT=1

export PATH=/home/luciano.pezzi/local/bin:$PATH
export JASPERINC=/home/luciano.pezzi/local/include
export JASPERLIB=/home/luciano.pezzi/local/lib
export LD_LIBRARY_PATH=/home/luciano.pezzi/local/lib:$LD_LIBRARY_PATH
```

Save and type in the terminal:

```
source .bashrc
```

2.6 Downloading COAWST

WARNING COAWST v3.6 is already in the repository within the Kerana cluster, as discussed in Section 2.4.

To download COAWST, send an email to Dr. John Warner (*jcwarner@usgs.gov*), one of the heads behind the coupled regional modeling.

After access is granted, with the user credentials and password provided by Dr. John Warner, type in the command the command below, changing the textit myusrname to your username.

```
svn checkout --username myusrname https://coawstmodel.sourcerepo.com/coawstmodel/COAWST
```

Add the COAWST folder to your Kerana desktop using *sftp*, as in the Section 2.3.

2.7 Automating the compilation of COAWST in Kerana

> **WARNING** This guide uses COAWST version 3..

To speed up the process, it is possible to automate some compilation steps. Enter the directory:

```
cd /scratch/name.surname/COAWST/WRF/arch
```

Open the file *Config.pl*:

```
nedit Config.pl
```

Look for the lines:

```
printf "\nEnter selection [%d-%d] : ",1,$opt ;
$response = <STDIN> ;
```

And replace <*STDIN*> to 42, as in the example below:

```
printf "\nEnter selection [%d-%d] : ",1,$opt ;
$response = 42 ;
```

Open the file *configure.defaults*:

```
nedit configure.defaults
```

Look for the *TRADEFLAG*, option, which is on line 1262, approximately:

```
TRADEFLAG = CONFIGURE_TRADEFLAG
```

And modify to:

```
TRADEFLAG = -traditional
```

These modifications will select the configurations of the Kerana cluster (*CRAY CCE (ftn/gcc): Cray XE and XC (dmpar)*), among those available to use COAWST, as in Figure 2.1.

```
  1. (serial)   2. (smpar)   3. (dmpar)   4. (dm+sm)   PGI (pgf90/gcc)
  5. (serial)   6. (smpar)   7. (dmpar)   8. (dm+sm)   PGI (pgf90/pgcc): SGI MPT
  9. (serial)  10. (smpar)  11. (dmpar)  12. (dm+sm)   PGI (pgf90/gcc): PGI accelerator
 13. (serial)  14. (smpar)  15. (dmpar)  16. (dm+sm)   INTEL (ifort/icc)
                                         17. (dm+sm)   INTEL (ifort/icc): Xeon Phi (MIC architecture)
 18. (serial)  19. (smpar)  20. (dmpar)  21. (dm+sm)   INTEL (ifort/icc): Xeon (SNB with AVX mods)
 22. (serial)  23. (smpar)  24. (dmpar)  25. (dm+sm)   INTEL (ifort/icc): SGI MPT
 26. (serial)  27. (smpar)  28. (dmpar)  29. (dm+sm)   INTEL (ifort/icc): IBM POE
 30. (serial)               31. (dmpar)                 PATHSCALE (pathf90/pathcc)
 32. (serial)  33. (smpar)  34. (dmpar)  35. (dm+sm)   GNU (gfortran/gcc)
 36. (serial)  37. (smpar)  38. (dmpar)  39. (dm+sm)   IBM (xlf90_r/cc_r)
 40. (serial)  41. (smpar)  42. (dmpar)  43. (dm+sm)   PGI (ftn/gcc): Cray XC CLE
 44. (serial)  45. (smpar)  46. (dmpar)  47. (dm+sm)   CRAY CCE (ftn/gcc): Cray XE and XC
 48. (serial)  49. (smpar)  50. (dmpar)  51. (dm+sm)   INTEL (ftn/icc): Cray XC
 52. (serial)  53. (smpar)  54. (dmpar)  55. (dm+sm)   PGI (pgf90/pgcc)
 56. (serial)  57. (smpar)  58. (dmpar)  59. (dm+sm)   PGI (pgf90/gcc): -f90=pgf90
 60. (serial)  61. (smpar)  62. (dmpar)  63. (dm+sm)   PGI (pgf90/pgcc): -f90=pgf90
```

Figure 2.1. Computational options available for selection when compiling COAWST.

Now, in the same file, look for the following lines:

```
printf "Compile for nesting? (1=basic, 2=preset moves, 3=vortex following) [default 1]: " ;
}
$response = <STDIN> ;
```

And change *<STDIN>* to the basic WRF atmospheric model nesting mode, as in the following example:

```
printf "Compile for nesting? (1=basic, 2=preset moves, 3=vortex following) [default 1]: " ;
}
$response = 1 ;
```

2.8 Compiling the MCT

WARNING This guide uses COAWST v 3.6.

Each new user must compile the MCT before compiling COAWST. The first step is to use the *setup_pgi.sh* file. This file was copied from the previous repository, it is essential to change the directories contained therein. So open the file:

```
nedit setup_pgi.sh
```

If necessary, change the directories according to the name of your COAWST folder and execute the file to load the necessary modules:

```
source setup_pgi.sh
```

The libraries will be activated, as shown in Figure 2.2:

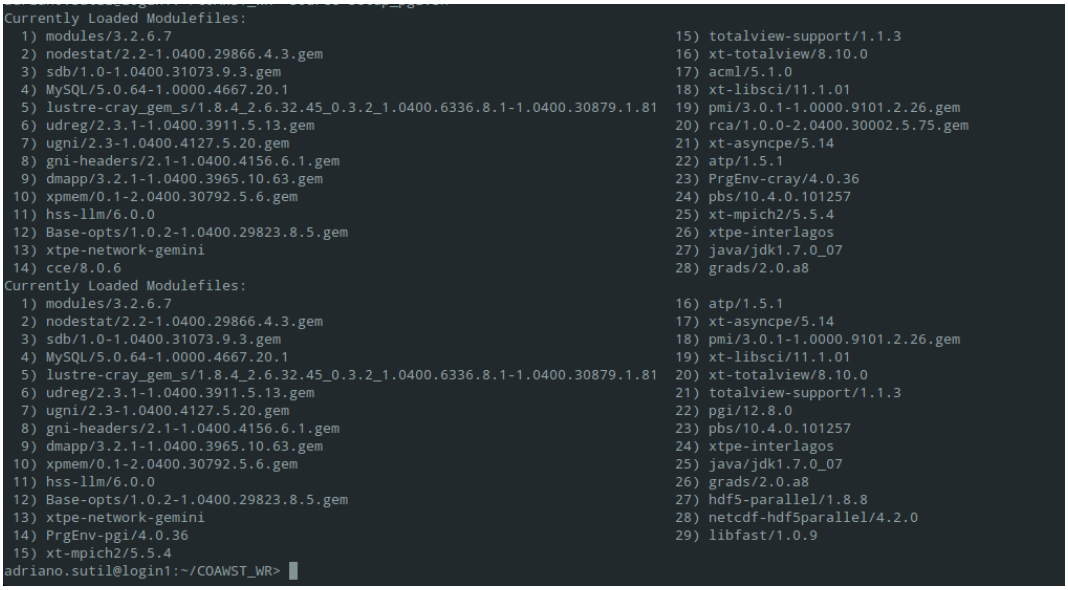

Figure 2.2. Modules activated in the cluster with the file *setup_pgi.sh* with user adriano.sutil.

Enter the MCT folder directory:

```
1 cd /home/name.surname/COAWST/Lib/MCT
```

Open the file *Makefile.conf*:

```
1 nedit Makefile.conf
```

And modify the file as follows:

WARNING Remember to change the *name.surname*!

```
FC              = ftn
FCFLAGS         = -O2
F90FLAGS        =
REAL8           = -r8
ENDIAN          = -Mbyteswapio
INCFLAG         = -I
INCPATH         =
MPILIBS         =
DEFS            = -DSYSLINUX -DCPRPGI
FPP             = cpp
FPPFLAGS        = -P -C -N -traditional
CC              = cc
ALLCFLAGS       = -DFORTRAN_UNDERSCORE_ -DSYSLINUX -DCPRPGI -O
COMPILER_ROOT   =
BABELROOT       =
PYTHON          =
PYTHONOPTS      =
FORT_SIZE       =
CRULE           = .c.o
90RULE          = .F90.o
F90RULECPP      = .F90RULECPP
INSTALL         = /home/name.surname/COAWST/Lib/MCT/install-sh -c
MKINSTALLDIRS   = /home/name.surname/COAWST/Lib/MCT/mkinstalldirs
abs_top_builddir= /home/name.surname/COAWST/Lib/MCT/
MCTPATH         = /home/name.surname/COAWST/Lib/MCT/mct
MPEUPATH        = /home/name.surname/COAWST/Lib/MCT/mpeu
EXAMPLEPATH     = /home/name.surname/COAWST/Lib/MCT/examples
MPISERPATH      =
libdir          = /home/name.surname/COAWST/Lib/MCT/pgi/lib
includedir      = /home/name.surname/COAWST/Lib/MCT/pgi/include
AR              = ar cq
RM              = rm -f
```

Install the MCT by typing the following commands:

```
make
make install
```

Observe the messages that appear in the terminal and look for errors. If not, the MCT was successfully compiled.

2.9 Compiling the Sandy test case

There are some test cases within COAWST to be compiled and worked on. In this case we'll compile Hurricane Sandy's project, which couples and nests WRF, ROMS and SWAN. First, it is necessary to know

the structure of COAWST files and folders.

The typical COAWST directory structure is exemplified in Figure 2.3. Mainly, we will use the folders *Projects* e *Work* to work on.

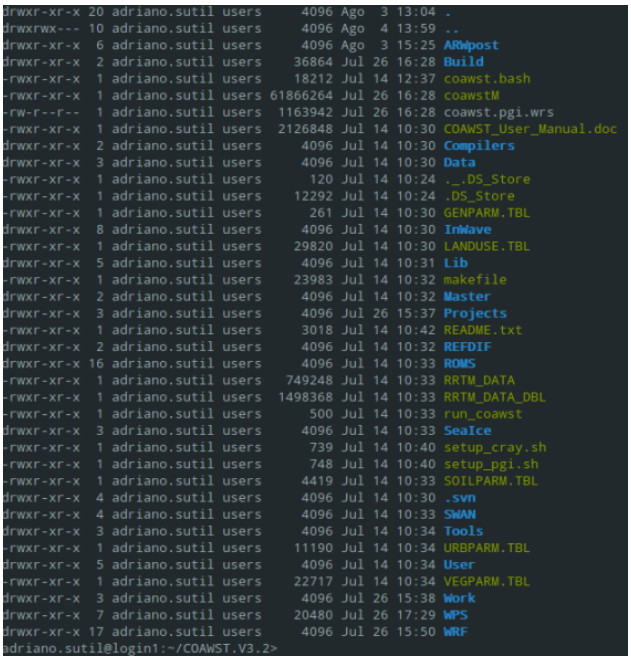

Figure 2.3. Representation of the main COAWST folder and subfolders.

2.9.1 Projects folder

To organize the projects, in the directory *COAWST/Projects/Sandy* are all the files used to simulate the Sandy case. The following files must be inside:

- Bound_spec_command
- coastline.mat
- coupling_sandy.in
- create_sandy_application.m
- hycom_info.mat
- ijcoast.mat
- multi_1.at_10m.dp.201210.grb2
- multi_1.at_10m.hs.201210.grb2
- multi_1.at_10m.tp.201210.grb2
- namelist.input
- ocean_sandy.in
- roms_master_climatology_sandy.m
- roms_narr_Oct2012.nc
- roms_narr_ref3_Oct2012.nc
- Rweigths.txt

- Sandy_bdy.nc
- Sandy_clm.nc
- Sandy_clm_ref3.nc
- sandy.h
- Sandy_ini.nc
- Sandy_ini_ref3.nc
- Sandy_init.hot
- Sandy_ref3_init.hot
- Sandy_roms_contact.nc
- Sandy_roms_grid.nc
- Sandy_roms_grid_ref3.nc
- Sandy_swan_bathy.bot
- Sandy_swan_bathy_ref3.bot
- Sandy_swan_coord.grd
- Sandy_swan_coord_ref3.grd
- scrip_sandy_moving.nc
- scrip_sandy_static.nc
- specpts.mat
- swan_narr_Oct2012.dat
- swan_narr_ref3_Oct2012.dat
- swan_sandy.in
- swan_sandy_ref3.in
- tide_forc_Sandy.nc
- TPAR10.txt
- TPAR11.txt
- TPAR12.txt
- TPAR13.txt
- TPAR14.txt
- TPAR15.txt
- TPAR16.txt
- TPAR17.txt
- TPAR18.txt
- TPAR1.txt
- TPAR2.txt
- TPAR3.txt
- TPAR4.txt
- TPAR5.txt
- TPAR6.txt
- TPAR7.txt
- TPAR8.txt
- TPAR9.txt
- USeast_bathy.mat
- Uweigths.txt
- Vweigths.txt
- wrfbdy_d01
- wrfinput_d01
- wrfinput_d02
- wrflowinp_d01

- wrflowinp_d02

2.9.2 Work folder

To make the management of simulations easier, it is suggested, for each new user, the creation of the *Work* folder in main COAWST directory, with each project inserted separately within it. It is in this folder that will be simulated the test case.

```
cd /scratch/name.surname/COAWST
mkdir Work
cd Work
mkdir Sandy
```

The folder */scratch/name.surname/COAWST/Work/Sandy* must contain the following files

- run_sandy.sh
- limpa.sh
- link.sh

The file *run_sandy.sh* will be used to start the simulation, *link.sh* creates symbolic links in the folder *Work*, that will be used by the models, and *limpa.sh* is used to clear the folder if an error occurs and a new integration needs to be started. The files are inside the folder */repositorio/work_coawst*.

Therefore:

```
cd /scratch/name.surname/repositorio/work_coawst
cp limpa.sh link.sh run_sandy.sh /scratch/name.surname/COAWST/Work/Sandy
```

Go to the directory */scratch/name.surname/COAWST/Work/Sandy* and open the file*run_sandy.sh*:

```
cd /scratch/name.surname/COAWST/Work/Sandy
nedit run_sandy.sh
```

Search for the following commands and modify the directories according to your username:

```
PBS -o /scratch/name.surname/COAWST/Work/Sandy/rws_total.out
ROOTDIR=/scratch/name.surname/COAWST
```

2.9.3 Compiling the test case

Go to the Sandy project folde:

```
/home/name.surname/COAWST/Projects/Sandy
```

Open the following files to make changes to the next steps:

- coupling_sandy.in
- swan_sandy.in
- swan_sandy_ref3.in
- ocean_sandy.in

```
nedit coupling_sandy.in swan_sandy.in swan_sandy_ref3.in ocean_sandy.in
```

Look for the command line below in the file *coupling_sandy.in*:

```
OCN_name = Projects/Sandy/ocean_sandy.in
```

And replace with:

```
OCN_name = /scratch/name.surname/COAWST/Projects/Sandy/ocean_sandy.in
```

In the files*swan_sandy.in* and *swan_sandy_ref3.in* complete all directory paths below:

Modify:

```
READGRID COORDINATES 1 'Projects/Sandy/Sandy_swan_coord.grd' 4 0 0 FREE
READINP BOTTOM 1 'Projects/Sandy/Sandy_swan_bathy.bot' 4 0 FREE
&READINP WIND 1 'Projects/Sandy/swan_namnarr_30Sep10Nov2012.dat' 4 0 FREE
INITIAL HOTSTART SINGLE 'Projects/Sandy/Sandy_init.hot'
```

By:

```
READGRID COORDINATES 1 '/scratch/name.surname/COAWST/Projects/Sandy/Sandy_swan_coord.grd' 4 0 0 FREE
READINP BOTTOM 1 '/scratch/name.surname/COAWST/Projects/Sandy/Sandy_swan_bathy.bot' 4 0 FREE
&READINP WIND 1 '/scratch/name.surname/COAWST/Projects/Sandy/swan_namnarr_30Sep10Nov2012.dat' 4 0 FREE
INITIAL HOTSTART SINGLE '/scratch/name.surname/COAWST/Projects/Sandy/Sandy_init.hot'
```

In the file *ocean_sandy.in* look for the command lines like below:

```
MyAppCPP = SANDY
VARNAME  = ROMS/External/varinfo.dat
GRDNAME == Projects/Sandy/Sandy_roms_grid.nc \
           Projects/Sandy/Sandy_roms_grid_ref3.nc
ININAME == Projects/Sandy/Sandy_ini.nc \
           Projects/Sandy/Sandy_ini_ref3.nc
NGCNAME =  Projects/Sandy/Sandy_roms_contact.nc
BRYNAME == Projects/Sandy/Sandy_bdy.nc
FRCNAME == Projects/Sandy/roms_narr_Oct2012.nc \
           Projects/Sandy/roms_narr_ref3_Oct2012.nc
```

And replace with:

```
MyAppCPP = Sandy
VARNAME  = /scratch/name.surname/COAWST/ROMS/External/varinfo.dat
GRDNAME == /scratch/name.surname/COAWST/Projects/Sandy/Sandy_roms_grid.nc \
           /scratch/name.surname/COAWST/Projects/Sandy/Sandy_roms_grid_ref3.nc
ININAME == /scratch/name.surname/COAWST/Projects/Sandy/Sandy_ini.nc \
           /scratch/name.surname/COAWST/Projects/Sandy/Sandy_ini_ref3.nc
NGCNAME =  /scratch/name.surname/COAWST/Projects/Sandy/Sandy_roms_contact.nc
BRYNAME == /scratch/name.surname/COAWST/Projects/Sandy/Sandy_bdy.nc
FRCNAME == /scratch/name.surname/COAWST/Projects/Sandy/roms_narr_Oct2012.nc \
           /scratch/name.surname/COAWST/Projects/Sandy/roms_narr_ref3_Oct2012.nc
```

Go back to the main COAWST folder and open the file *coawst.bash*:

```
cd /scratch/name.surname/COAWST
nedit coawst.bash
```

Search for the following commands and modify, if necessary:

```
export   COAWST_APPLICATION=JOE_TC
export   MY_ROOT_DIR=${HOME}/COAWST
export   MY_HEADER_DIR=${MY_PROJECT_DIR}/Projects/JOE_TC
```

By:

```
export   COAWST_APPLICATION=Sandy
export   MY_ROOT_DIR=${HOME}/COAWST
export   MY_HEADER_DIR=${MY_PROJECT_DIR}/Projects/Sandy
```

Activate the modules again into the file *setup_pgi.sh*, and then compile the project with the command:

```
./coawst.bash -j 4  1> coawst.pgi.sandy 2>&1 &
```

This command will create the text file *coawst.pgi.sandy* where you can follow the progress of the compilation. Open the text file with the following command and look for the final message, as in Figure 2.4.

```
nedit coawst.pgi.sandy
```

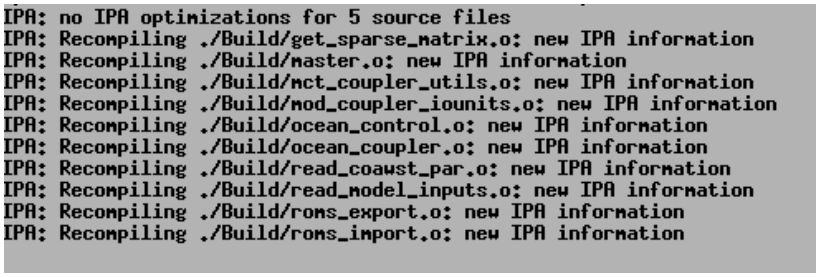

Figure 2.4. Final message after compiling COAWST.

If you want to follow the progress of the compilation through the terminal, use the command:

```
tail -f coawst.pgi.sandy
```

WARNING The compilation process is long!

Ready! In the main COAWST directory, a file called *coawstM* will be created. In this file all the information about your project will be compiled. Now with COAWST compiled, we will start the test case.

2.10 Simulating the Sandy Test Case

To simulate the case, search for the file in *Work/Sandy*. Type it:

```
cd /scratch/name.surname/COAWST/Work/Sandy
nedit run_sandy.sh
```

WARNING The *Work* folder should contain the files *clean.sh*, *link.sh* and *run_sandy.sh*. They can be found in the folder used as a repository. See Section 2.9.2.

When opening the file, check if the directories are in accordance with your username and type the command below to start the integration.

```
qsub run_sandy.sh
```

WARNING The command *qsub* will submit you job. It will send the executed script to a batch of the cluster, reserving a part of the processors for its simulation.

The process will generate two files to follow the evolution of the simulation: *log.out* and *log.err*. To open, use:

```
nedit log.out log.err
```

Or look directly at the terminal with the command:

```
tail -f log.out
```

The outputs of the simulations will be stored in the *Work/Sandy* folder. If an error occurs, clean the desktop with the command:

```
./limpa.sh
```

WARNING The simulation of the test case Sandy may take several hours when integrating using 3 processors.

3. COAWST features

So far we have learned how to use the Kerana cluster and how to compile and run a simple COAWST test case. From now on we will enter into the specifics of the models, such as changing the number of processors and the rate of exchange of information between them.

3.1 Structural model files

As you may have noticed when simulating the Sandy test case, the models have files that assist the user about how to setup the project

ROMS uses the *sandy.h* file as a file containing the C pre-processing options that define the project. Access the website*https://www.myroms.org/wiki/cppdefs.h* to know more about the available options into this file. ROMS also uses the *ocean_sandy.in* as standard input for running the model. This file defines the spatial dimensions of the project and parameters that are not informed during compilation, such as time steps, coefficients and physical constants, configuration of vertical coordinates, flags for control the output frequency, among other factors. You can learn more about this file by accessing the site *https://www.myroms.org/wiki/ocean.in*.

WRF uses the file *namelist.input* to manage information about the project, as well as physical parameterization schemes that will be used. To learn about the file description, visit *https://esrl.noaa.gov/gsd/wrfportal/namelist_input_options.html*. To learn about the physical options of the model and the references of each one, visit *http://www2.mmm.ucar.edu/wrf/users/phys_references.html*.

SWAN uses the file *swan_sandy.in* as a manager. It describes several parameters, such as the project description, the input data, the grid and the initial and boundary conditions, the wave physics parameterizations, among others. To learn more about configuring the file, visit the *User Manual* tab in the website *http://swanmodel.sourceforge.net/* and look for the section *Description of commands*.

3.2 Modifying the number of processors

3.2.1 ROMS

The processors are located in the *ocean.in* file, which is located in the *Projects* folder, and are called *NtileI* and *NtileJ*. An example is in Figure 3.1. In this case, ROMS will reserve 320 processors to run, since 16 x 20 = 160.

```
! Domain decomposition parameters for serial, distributed-memory or
! shared-memory configurations used to determine tile horizontal range
! indices (Istr,Iend) and (Jstr,Jend), [1:Ngrids].

      NtileI == 16                              ! I-direction partition
      NtileJ == 20                              ! J-direction partition
```

Figure 3.1. Representation of the number of processors used in ROMS.

3.2.2 WRF

To change the number of WRF processors, it is necessary to modify the file *namelist.input*. You will find the variables *nproc_x* and *nproc_y*, as in Figure 3.2. In this case, 320 processors will be reserved for the atmospheric model.

```
nproc_x                                     = 16,
nproc_y                                     = 20,
```

Figure 3.2. Representation of the number of processors for the WRF.

3.2.3 SWAN

The SWAN *.in* file does not discriminate the numbers of processors used, so just change the number number of processors in *coupling.in*, as will be shown in the subsection below.

3.2.4 COAWST

Now that the number of processors have been modified, the coupler needs to be informed about the change. This information is communicated through the file *coupling.in*. It should contain the total number of processors to be used by the ROMS, WRF and SWAN models, as in the figure 3.3:

```
!
! Number of parallel nodes assigned to each model in the coupled system.
! Their sum must be equal to the total number of processors.

   NnodesATM =  320                  ! atmospheric model
   NnodesWAV =  64                   ! wave model
   NnodesOCN =  320                  ! ocean model
```

Figure 3.3. Representation of the number of processors for each COAWST module.

The *NnodesATM* refers to the total number of processors used by WRF, *NnodesWAV* is the total used by SWAN and *NnodesOCN* is total used by ROMS. Just change according to the total number of processors used in the previous steps.

Finally, it is necessary to modify the total number of processors in *run.sh*,used to submit the experiment. Add the total number of processors used by the three models, following the equation 3.1:

$$TotalProc = NnodesATM + NnodesWAV + NnodesOCN \tag{3.1}$$

Where*TotalProc* is the sum of all processors used in the models.

Now open the file *run.sh*, located inside the folder *Work*, and look for the following line:

```
PBS -l mppwidth= 3
```

And for the line:

```
aprun -n 36 coawstM ./coupling.in 1> log.out 2> log.err
```

Modify the number *3* by the total number of processors used.

3.3 Modifying the coupling time interval between models

To modify the information exchanged between models, open the file *coupling.in* and modify the variables *TI_ATM2WAV*, *TI_ATM2OCN*, *TI_WAV2ATM*, *TI_WAV2OCN*, *TI_OCN2WAV*, *TI_OCN2ATM*, as in Figure 3.4.

WARNING The unit of the information exchange rate is defined in seconds.

```
! Time interval (seconds) between coupling of models.

  TI_ATM2WAV =   900.0d0              ! atmosphere to wave coupling interval
  TI_ATM2OCN =   900.0d0              ! atmosphere to ocean coupling interval
  TI_WAV2ATM =   900.0d0              ! wave to atmosphere coupling interval
  TI_WAV2OCN =   900.0d0              ! wave to ocean coupling interval
  TI_OCN2WAV =   900.0d0              ! ocean to wave coupling interval
  TI_OCN2ATM =   900.0d0              ! ocean to atmosphere coupling interval
```

Figure 3.4. Information exchange interval between models used in COAWST. In this example, the exchange will occur every 900 seconds.

4. Building the WRF

Now that we have learned how to simulate a test case and change the coupling rate and number of processors, we will begin the process of creating a specific grid and the initial and boundary conditions for the WRF using the NCEP Climate Forecast System Reanalysis (CFSR; Saha et al., 2010).

4.1 Compiling WRF in Kerana cluster

It is recommended to copy the WRF folder inside COAWST to your work root area, in order to avoid conflicts if you choose to use the WRF without coupling to the COAWST model. Therefore:

```
cd /scratch/name.surname/COAWST
cp -r WRF /scratch/nome.dsobrenome
```

Activate the modules in the *setup_pgi.sh* file with the command:

```
source setup_pgi.sh
```

Enter the copy folder of the WRF (*/home/name.surname/WRF*) and run:

```
./configure
```

WARNING The next step can be automated. If you choose the automated compilation, see Section 2.7.

If you have automated the compilation process, as shown in Section 2.7, the files *real.exe*, *wrf.exe*, *tc.exe* and *ndown.exe* will be created. If you choose the manual option on the Kerana cluster, look down for the option *Cray XC CLE / Linux x86 _64, Cray compiler with gcc (dmpar)*.

In the next option, the following message will appear:

```
Compile for nesting? (1=basic, 2=preset moves, 3=vortex following) [default 1]:
```

Choose option 1.

WARNING End of the automated build process.

Type:

```
compile em_real
```

The *real.exe*, *wrf.exe*, *tc.exe* and *ndown.exe* will be generated in the */home/name.surname/WRF/test/em_real*.

4.2 WRF Preprocessing System (WPS)

To build the initial and boundary conditions of the WRF, we will use WRF Preprocessing System (WPS). The WPS is a set of three programs that prepare the input data for the simulations. It consists of the following modules:

- ***geogrid***: Defines the model domain and interpolates the geographic data for the grid;
- ***ungrib***: Extract weather fields from *.grib* files;
- ***metgrid***: Interpolates the weather fields extracted by ungrib to the model grid defined by metrid.

WPS is controlled by the *namelist.wps* file and is outlined in Figure 4.1.

For more information about WPS, visit: *http://www2.mmm.ucar.edu/wrf/OnLineTutorial/*.

After creating these files, the *real.exe* is used to interpolate the meteorological fields to ηlevel.

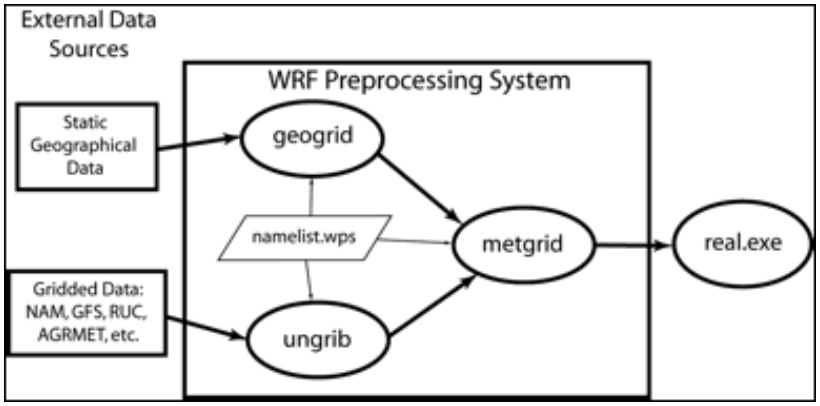

Figure 4.1. WPS schemeatic.
Author: Duda (2008)

.

4.2.1 Downloading WPS

WPS is included in the COAWST package, however WPS can be downloaded by visiting *http://www2.mmm.ucar.edu/wrf/users/download/get_source.html*). Download it and add the *tar.gz* file inside the cluster (preferably within the COAWST folder)) with *sftp*:

```
sftp -P2000 name.surname@acesso-hpc.cptec.inpe.br
cd COAWST
put WPSV3.9.0.1.tar.gz
```

To unzip, use *ssh* to enter the cluster and type:

```
ssh -Y name.surname@acesso-hpc.cptec.inpe.br -p 2000
cd COAWST
tar -xvzf WPSV3.9.0.1.tar.gz
```

4.2.2 Compiling WPS in the Kerana cluster

WARNING As stated earlier in Section 4.2.2, WPS is included with COAWST. We recommend o use this version.

To compile the WPS and generate the executables, it is necessary to activate the libraries with *setup_pgi.sh*, found in the directory */home/name.surname/repository*. Activate them with the command:

```
source setup_pgi.sh
```

Inside the WPS folder, enter the following command:

```
./configure
```

You will be asked which machine and compiler will be used. Choose the option *Cray XE / XC CLE / Linux x86 _64, PGI compiler (serial)*. In this case, a message will be generated that Fortran is not compatible with C and NetCDF, but ignore it.

Open *configure.wps* file:

```
nedit configure.wps
```

Modify:

```
WRF_DIR  = ../WRFV3
SFC      = ftn
SCC      = gcc
DM_CC    = cc
DM_FC    = ftn
FFLAGS   = -N255 -f free -h byteswapio
F77FLAGS = -N255 -f fixed -h byteswapio
```

By:

```
WRF_DIR  = /scratch/name.surname/WRF
SFC      = ftn
SCC      = gcc
DM_CC    = gcc
DM_FC    = ftn
FFLAGS   =
F77FLAGS =
```

Save the changes and start the compilation with the command:

```
./compile
```

You should generate the executables *metgrid.exe* and *geogrid.exe*. However, it is possible that *ungrib.exe* is not generated. In this case, repeat:

```
./configure
```

Choose the option *Linux x86_64, PGI compiler (dmpar)*.

Open *configure.wps* file again, modify:

```
WRF_DIR = ../WRFV3
SFC     = pgf90
SCC     = pgcc
DMFC    = mpif90
DMCC    = mpicc
```

By:

```
WRF_DIR = /home/name.surname/WRF
SFC     = ftn
SCC     = gcc
DMFC    = ftn
DMCC    = gcc
```

The installer will generate only the *ungrib.exe*.

4.3 Building your project using CFSR

A database as option to use for simulations is the NCEP Climate Forecast System Reanalysis (CFSR) (*http://rda.ucar.edu/datasets/ds093.0*). This database is a reanalysis, from January 1979 to December 2010, where a coupled model (atmosphere-ocean-land surface and sea ice) assimilates orbital data, research cruises, oceanographic buoys and weather stations. This database has vertical resolution with 38 levels, extending from the surface to 1 hPa, with a 6-hour temporal resolution and horizontal of 0.5°for pressure levels data and 0.312°for variables on the surface.

To access the data it is necessary to register on the site. After doing this, enter the database link, click on the*Data Acess* and then, *Get a subset*.

On the next page, as seen in Figure 4.2, write the temporal selection, and select in *Parameter presets* one of the three parameters of the WRF presets: (*Pressure*, *Surface* and *SST*).

WARNING Only one parameter (*Pressure*, *Surface* and *SST*) can be downloaded at a time, therefore you need to repeat this step three times.

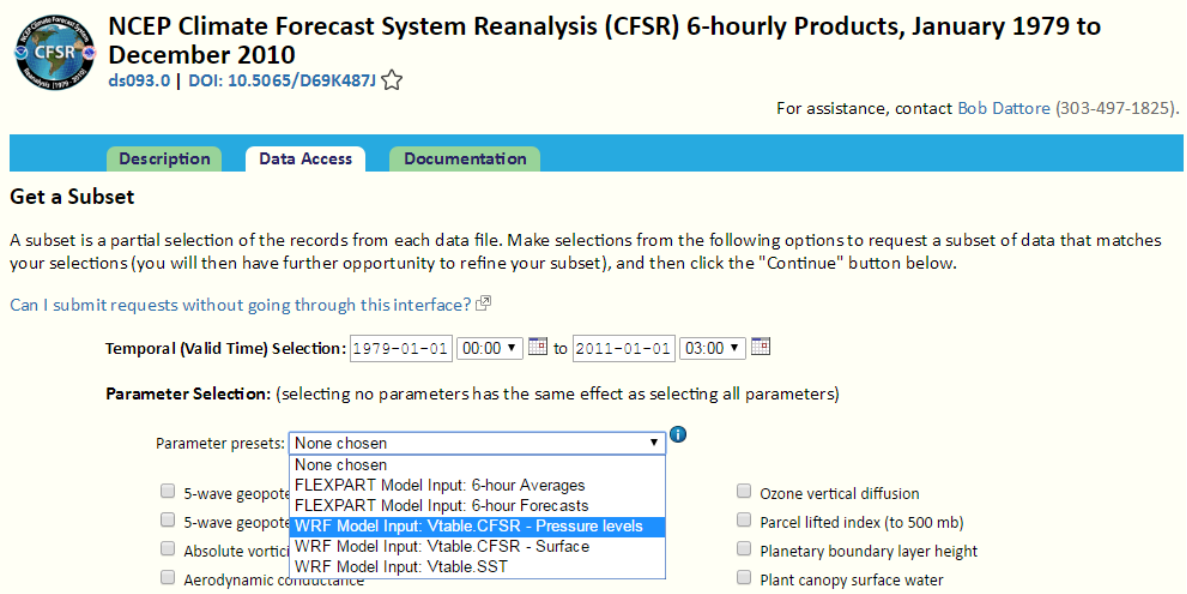

Figure 4.2. Screenshot of the CFSR data page.

Download the data (as *GRIB*) and separate it into three folders according to the parameters of each one: SST, Surface and Pressure. Compress them and put them in the cluster:

```
tar -cvzf SST.tar.gz SST/
tar -cvzf Pressure.tar.gz Pressure/
tar -cvzf Surface.tar.gz Surface/
ssh -Y name.surname@acesso-hpc.cptec.inpe.br -p 2000
mkdir Data_CFSR
exit
sftp -P2000 name.surname@acesso-hpc.cptec.inpe.br
cd Data_CFSR
put SST.tar.gz
put Pressure.tar.gz
put Surface.tar.gz
exit
ssh -Y name.surname@acesso-hpc.cptec.inpe.br -p 2000
cd Data_CFSR
tar -xvzf SST.tar.gz
tar -xvzf Pressure.tar.gz
tar -xvzf Surface.tar.gz
```

4.3.1 *geogrid*

As previously mentioned, textit geogrid generates the grid domain using geographic data. The data can be obtained from this website: *http://www2.mmm.ucar.edu/wrf/users/download/get_sources_wps_geog.html*, or directly from the guide repository:

```
/scratch/name.surname/repositorio/COAWST/WPS/geog
```

With the CFSR and *geogrid* data in hand, enter into the WPS directory and open *namelist.wps*. The file structure is shown in Figure 4.3:

```
nedit namelist.wps
```

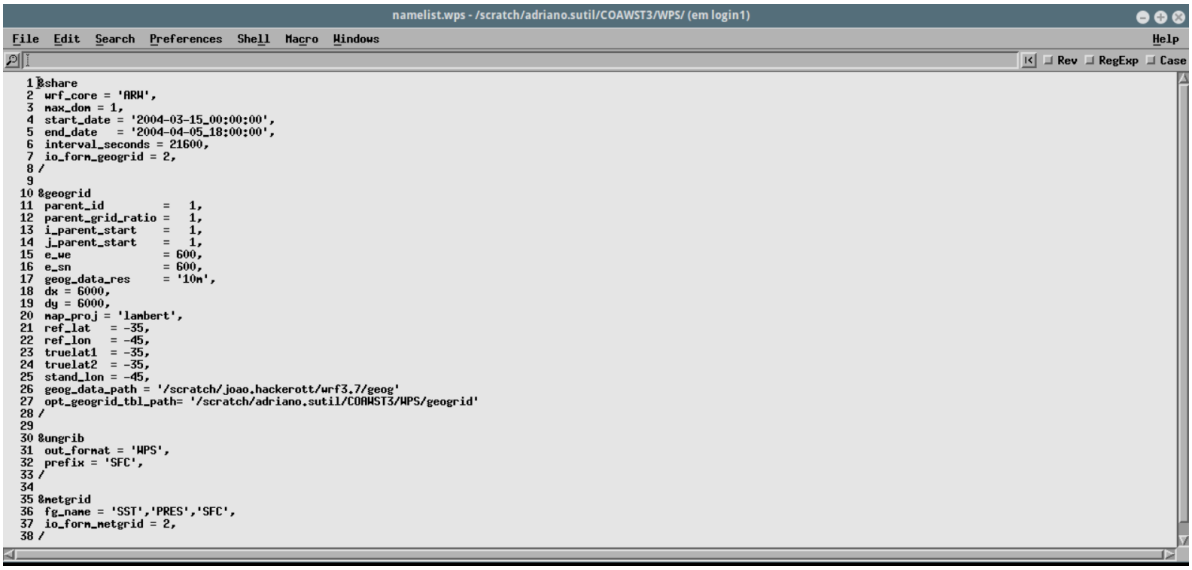

Figure 4.3. *namelist.wps* example.

Change the *geog_data_path* path to the directory where geographic data is located (*geog folder*), *geog_data_res* if you want to use other geographic data and *opt_geogrid_tbl_path*, which is the *geogrid* directory.

The WPS uses a ground zero point defined by the user as the latitude and longitude degrees in *ref_lat* and *ref_lon*). It will generate the grid from that point and through the chosen spatial resolution. Take as example the Figure 4.3: a simulation will be prepared with 6 km of spatial resolution (*dx* and *dy* = 6000), in Lambert projection, with 600 grid points. Using as reference latitude -35°longitude -45°, a grid will be created with 600 points in the west-east direction (*e_we*) and 600 points in the south-north direction (*e_sn*), with each point having a spacing of 6000 meters (6 km) between them.

To start *geogrid*, you need a file with a Shell extension (*.sh*), which submits program to be executed in the cluster. It can be found in the */repository/WPS_scripts* directory. Move the contents of the folder to the WPS directory with the commands:

```
cd /home/name.surname/repositorio/WPS_scripts
mv qsub_geogrid.sh qsub_ungrib.sh qsub_metgrid.sh /home/name.surname/COAWST/WPS
```

The structure of the *qsub_geogrid.sh* file is shown in Figure 4.4. Modify the directory according to your user.

```
#!/bin/sh
#PBS -l mppwidth=1
#PBS -N GEOGRID
#PBS -j oe
#PBS -o Joe_test.out
#PBS -l walltime=02:30:00
#PBS -q workq
  echo "Running GEOGRID on KERANA"
#
  export MPICH_ENV_DISPLAY=1
  export MPICH_ABORT_ON_ERROR=1
  export MPICH_RANK_REORDER_DISPLAY=1
  export MPICH_RANK_REORDER_METHOD=1
  export MALLOC_MMAP_MAX_=0
  export MALLOC_TRIM_THRESHOLD_=536870912
  export OMP_NUM_THREADS=1
#
  EXECDIR=/scratch/nome.sobrenome/COAWST/WPS

  cd $EXECDIR

  aprun -n 1 geogrid/src/geogrid.exe  1> log.out 2> log.err

  \rm geogrid.log.00*
```

Figure 4.4. *qsub_geodrid.sh* example.

To run *geogrid*, use *qsub* command:

```
1 qsub qsub_geodrid.sh
```

Two files will be generated: *log.err* e *log.out*. you can follow how the program is being executed and search for errors. The program completion message is showned in Figure 4.5, in the file *log.out*.

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!  Successful completion of geogrid.        !
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
Application 593294 resources: utime ~813s, stime ~1s
```

Figure 4.5. Example of completion of *geogrid*.

When completing the execution of *geogrid*, the file *geo_em_d01.nc* will be generated. You can view the NetCDF file with Ncview:

```
1 module load netcdf
2 ncview geo_em_d01.nc
```

You will always need to run *geogrid* until you find a domain that is suitable for your project, since WPS does not have a graphical interface. One solution to work around the problem is to use NCAR Command Language version 6.4 (NCL; UCAR, 2017) to plot the image of the chosen domain. This will be the subject of the next subsection.

4.3.2 Using the NCL to plot the grid domain

To install the NCL, move the *NCL* folder inside the repository:

```
mv /scratch/name.surname/repositorio/NCL /scratch/name.surname
```

Open the *.bashrc* file:

```
cd
nedit .bashrc
```

Add the following command lines, changing to your username:

```
export NCARG_ROOT=/scratch/name.surname/NCL
export PATH=$NCARG_ROOT/bin:$PATH
```

Save the file, reload the modules inside *.bashrc* and then execute NCL.

```
source .bashrc
ncl
```

Check if the NCL has been initialized as in Figure 4.6.

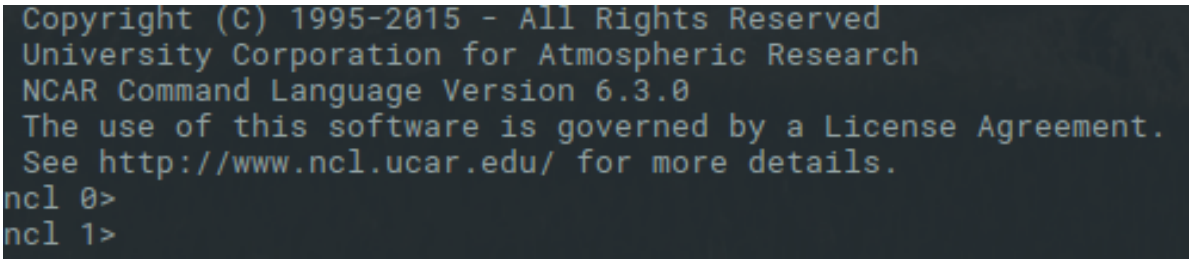

Figure 4.6. Example of NCL initialization.

Enter the repository and open the *plotgrids.ncl* file. This script generates the domain image from the data in the WPS *namelist.wps* file.

```
cd /scratch/name.surname/repositorio
nedit plotgrids.ncl
```

Modify the *namelist.wps* directory according to your user area:

```
filename = "/home/name.surname/COAWST/WPS/namelist.wps"
```

Run the code with the command:

```
ncl plotgrids.ncl
```

The code will search for the grid points and the domain resolution through the file *namelist.wps* and show it on the screen, as shown in Figure 4.7. Repeat the process until you find a domain that suits your needs.

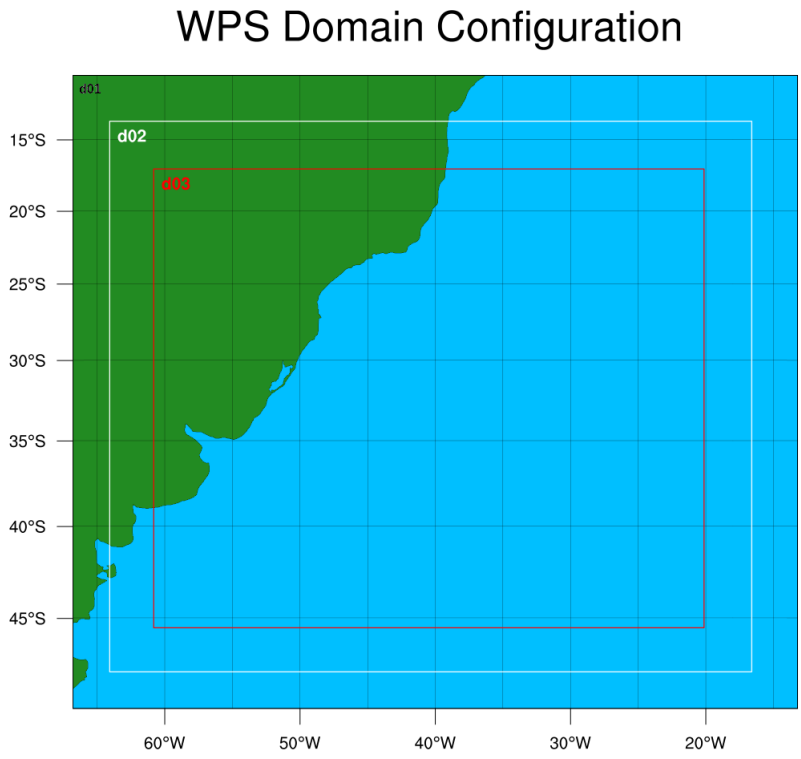

Figure 4.7. Figure generated by the *plotgrids.ncl* file. In this example, three domains were generated.

4.3.3 *ungrib*

With the domain prepared by *geogrid*, we can proceed to *ungrib*, which extracts the data from the *Grib* files. We will start creating the SST data. Open *namelist.wps* and change the *prefix* to *SST*, in the *& ungrib* section, as shown in Figure 4.8.

```
&ungrib
 out_format = 'WPS',
 prefix = 'SST',
/
```

Figure 4.8. *&ungrib* example.

Import the Variable Table for SST through a symbolic link. Type in the terminal:

```
ln -sf ungrib/Variable_Tables/Vtable.SST Vtable
```

WARNING The *Vtable* is used to read the files in *Grib* format. It is mandatory to use the corresponding *Vtable* to the chosen database. You can consult them at *WPS/ungrib/Variable_Tables*.

Create the symbolic links with the SST data through the *link_grib.csh* file:

```
./link_grib.csh /scratch/name.surname/Dados_CFSR/SST/*
```

Open the *qsub_ungrib.sh* file and modify the path according to your user and type:

```
qsub qsub_ungrib.sh
```

WARNING The *qsub_ungrib.sh* file is located in the */repository/WPS_scripts* folder.

Several files will be created with the initial *SST:* followed by the date chosen for simulation. To check if everything went well, look for the message in Figure 4.9 at the end of the file *log.out*.

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!  Successful completion of ungrib.    !
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
Application 593300 resources: utime ~18s, stime ~1s
```

Figure 4.9. Final message in the *log.out* file when running *ungrib*.

We will proceed to the CFSR surface data. Change the *prefix* in *namelist.wps* (Figure 4.8). Modify *SST* by *SFC* and save the modification.

Import the CFSR *Variable Table* with the symbolic link creation command:

```
ln -sf ungrib/Variable_Tables/Vtable.CFSR Vtable
```

Create the symbolic links to the CFSR surface data with the command below and run *ungrib* again:

```
./link_grib.csh /scratch/name.surname/Dados_CFSR/Surface/*
qsub qsub_ungrib.sh
```

Look for the final message as shown in Figure 4.9.

Change the *prefix* of *namelist.wps* (Figure 4.8), replace *SFC* with *PRES* and save the file.

Create the symbolic links to the pressure data and run *ungrib*:

```
./link_grib.csh /scratch/name.surname/Dados_CFSR/Pressure/*
qsub qsub_ungrib.sh
```

Finally, look for the final message as identified in Figure 4.9. At the end of these steps, there will be several files with the initials *SST*, *PRES*, *SFC* followed by the dates of the chosen period.

4.3.4 *metgrid*

To interpolate the data generated by *ungrib.exe*, open *namelist.wps* and change on the *fg_name* tab the names used in *ungrib*. In the previous case, *PRES*, *SFC* and *SST* were used, as in the example in Figure 4.10:

```
&metgrid
 fg_name = 'PRES','SFC','SST',
 io_form_metgrid = 2,
/
```

Figure 4.10. *metgrid* example.

Open and then change the *qsub_metgrid.sh* file path and run:

```
qsub qsub_metgrid.sh
```

Move the files generated by *metgrid* (*met_em.d01**) to the real WRF case directory:

```
mv met_em.d01* /home/name.surname/WRF/test/em_real
```

> **WARNING** If you are an experienced user, you can create symbolic links pointing to the *met* files instead of moving them.

4.3.5 *real*

We will use the *real.exe* program to generate the files that will be used in WRF. Open the file *namelist.input*, which is in the WRF folder (*/home/name.surname/WRF/test/em_real*), and modify it according to your chosed domain and simulation time in *namelist.wps*.

For the WRF to simulate the SST, it is necessary to include the following variables at the end of the section *&time_control* (Figure 4.11):

```
io_form_auxinput4  = 2,
auxinput4_inname   = "wrflowinp_d<domain>",
auxinput4_interval = 360,
```

The *io_form_auxinput4* refers to the final format of the textitwrflowinp file that will be generated by the *real*. The *auxinput4_inname* is the name of the boundary condition file for SST and *auxinput4_interval* is the time interval, in minutes, of the boundary file.

```
&time_control
run_days                            = 5,
run_hours                           = 0,
run_minutes                         = 0,
run_seconds                         = 0,
start_year                          = 2008,
start_month                         = 11,
start_day                           = 21,
start_hour                          = 00,
start_minute                        = 00,
start_second                        = 00,
end_year                            = 2008,
end_month                           = 11,
end_day                             = 25,
end_hour                            = 18,
end_minute                          = 00,
end_second                          = 00,
interval_seconds                    = 21600,
input_from_file                     = .true.,
history_interval                    = 360,,
frames_per_outfile                  = 80,
restart                             = .false.,
restart_interval                    = 50000,
io_form_history                     = 2
io_form_restart                     = 2
io_form_input                       = 2
io_form_boundary                    = 2
debug_level                         = 0
io_form_auxinput4                   = 2
auxinput4_inname                    = "wrflowinp_d<domain>"
auxinput4_interval                  = 360,
/
```

Figure 4.11. *&time_control* example.

Also, in the *&physics* (Figure 4.12) in the *namelist.input* the option to update the SST:

```
1 sst_update = 1,
```

```
&physics
sst_update                          = 1,
mp_physics                          = 6,
ra_lw_physics                       = 4,
ra_sw_physics                       = 3
swint_opt                           = 1,
sf_sfclay_physics                   = 1,
sf_surface_physics                  = 2,
bl_pbl_physics                      = 1,
cu_physics                          = 1,
isfflx                              = 1,
ifsnow                              = 1,
icloud                              = 1,
surface_input_source                = 1,
num_soil_layers                     = 4,
sf_urban_physics                    = 0,
sst_skin                            = 0,
```

Figure 4.12. *&physics* example.

After completing the modifications, you must use the file *qsub_real.sh* to submit the job. The file is located in

the */repository/WRF_scripts* directory. Move the file to the *em_real* folder, change the directory according to your user and execute:

```
cd /home/name.surname/repositorio/WRF_scripts
mv qsub_real.sh /home/name.surname/WRF/test/em_real
qsub qsub_real.sh
```

WARNING The *qsub_real.sh* file is located in the */repository/WRF_scripts* folder.

To certify success in running *real*, look at the end of the *log.out* file for the success message as shown in Figure 4.13.

```
d01 2007-02-18_00:00:00 real_em: SUCCESS COMPLETE REAL_EM INIT
d01 2007-02-18_00:00:00 Timing for loop #   41 =          2 s.
d01 2007-02-18_00:00:00 real_em: SUCCESS COMPLETE REAL_EM INIT
d01 2007-02-18_00:00:00 real_em: SUCCESS COMPLETE REAL_EM INIT
d01 2007-02-18_00:00:00 Timing for loop #   41 =          2 s.
d01 2007-02-18_00:00:00 real_em: SUCCESS COMPLETE REAL_EM INIT
d01 2007-02-18_00:00:00 real_em: SUCCESS COMPLETE REAL_EM INIT
d01 2007-02-18_00:00:00 real_em: SUCCESS COMPLETE REAL_EM INIT
d01 2007-02-18_00:00:00 real_em: SUCCESS COMPLETE REAL_EM INIT
Application 593290 resources: utime ~11862s, stime ~117s
```

Figure 4.13. Successful completion of*real*.

Upon completing *real*, three files will be generated: *wrfbdy_d01*, *wrfinput_d01* and *wrflowinp_d01*, if you have chosen only one domain. After that, the WRF conditions are ready to be copied to your project folder in COAWST:

```
cp wrfbdy_d01 wrfinput_d01 wrflowinp_d01 /home/name.surname/COAWST/Projects/project_name
```

4.4 Using the WRF

With the files ready, it is possible to start the simulation of your project using only the WRF.

To run the simulation on the cluster, it is necessary to use the file *qsub_wrf.sh*. It is located in the */repository/WRF_scripts* directory. Move the file to the WRF *in_real* folder, modify the directory according to your user and save:

```
cd /home/name.surname/repositorio/WRF_scripts
mv qsub_wrf.sh /home/name.surname/WRF/test/em_real
nedit qsub_wrf.sh
```

To start the simulation, type:

```
qsub qsub_wrf.sh
```

WARNING The *qsub_wrf.sh* file is located in the */repository/WRF_scripts* folder.

Follow the evolution of the job with the *log.out* and *log.err* files. If you want to have the information updated by the terminal, type:

```
tail -f log.out
```

5. Construindo o ROMS

5.1 Instalando as bibliotecas do Python no computador pessoal

Antes de gerar os arquivos de condições de forçamento e contorno oceânico e a grade para o ROMS, é necessário instalar as bibliotecas e dependências. Nesta seção serão disponibilizados os endereços para baixá-las, bem como os comandos no terminal via *apt-get*.

Existem duas maneiras de instalar as bibliotecas necessárias: manualmente, e através do Anaconda. Este último é uma plataforma gratuita e de código aberto em Python e R e possui um gerenciador de pacotes chamado Conda, que facilita a instalação de bibliotecas. Neste guia, apresentarei as duas opções. Pela praticidade, sugiro instalar usando o Conda (Seção 5.1.2), porém cuidado para conflito de versões, pois os repositórios do Conda são atualizados constantemente.

> **ATENÇÃO** A construção do ROMS deverá ser feita no seu próprio computador e não mais no Kerana, como feito anteriormente com o WRF.

5.1.1 Instalando manualmente

Abra o terminal, e crie uma pasta na sua *home* chamada *libsmodels*. Nela serão adiconados os arquivos baixados e as bibliotecas.

```
1 sudo mkdir libsmodels
```

Caso não tenha o *gfortran* e o *g++* instalados, instale via *apt-get*.

```
sudo apt-get install
sudo apt-get install g++
```

A seguir, baixe o OpenMPI 2.0.1 (*https://www.open-mpi.org/software/ompi/v2.0/*), extraia o arquivo dentro da pasta *libsmodels* e digite no terminal:

```
export F77=gfortran
export FC=gfortran
export FC=gfortran
export CC=gcc
export CXX=g++
export FFLAGS="-m64 -fdefault-integer-8"
export FCFLAGS="-m64 -fdefault-integer-8"
export CFLAGS=-m64
export CXXFLAGS=-m64
```

Entre na pasta do OpenMPI e digite:

ATENÇÃO Altere o nome do computador abaixo (*usuario*) pelo nome do seu computador.

```
./configure --prefix=/home/usuario/libsmodels
sudo make
sudo make check
sudo make install
```

Volte até a sua */home/usuario* e abra o arquivo oculto *.bashrc* através do comando *gedit .bashrc* e nas linhas finais do arquivo escreva:

```
cd /home/usuario
gedit .bashrc
export PATH=/home/usuario/libsmodels/bin:$PATH
export LD_LIBRARY_PATH=/home/usuario/libsmodels/lib:$LD_LIBRARY_PATH
export PATH=/home/usuario/libsmodels/include:$PATH
```

Salve o arquivo e digite o comando a seguir para atualizar o terminal e aplicar as mudanças.

```
source .bashrc
```

Teste a instalação do OpenMPI está correta, digite no terminal:

```
ompi_info -a grep 'Fort integer size'
```

O resultado deverá ser:

```
Fort integer size: 8
```

Caso não tenha instalado no seu computador, será necessário instalar o *m4*, *make* e *perl*. Para checar se o seu computador já possui estes programas instalados:

```
which m4
which make
which perl
```

Caso a resposta seja negativa, instale a partir dos comandos a seguir:

```
sudo apt-get install m4
sudo apt-get install make
sudo apt-get install perl
```

Instale o *szip 2.1* (*https://www.hdfgroup.org/HDF5/release/obtain5.html*). Baixe-o, descompacte na pasta */home/usuario/libsmodels* e entre na pasta do *szip* digite:

```
export F77=gfortran
export FC=gfortran
export CC=gcc
export CXX=g++
export FFLAGS="-m64 -fdefault-integer-8"
export FCFLAGS="-m64 -fdefault-integer-8"
export CFLAGS=-m64
export CXXFLAGS=-m64
./configure --prefix=/home/usuario/libsmodels
sudo make
sudo make check
sudo make install
```

Instale o *zlib 1.2.8* (*http://zlib.net/*). Baixe-o, descompacte na pasta */home/usuario/libsmodels* e entre na pasta do *zlib* digite:

```
export F77=gfortran
export FC=gfortran
export CC=gcc
export CXX=g++
export FFLAGS="-m64 -fdefault-integer-8"
export FCFLAGS="-m64 -fdefault-integer-8"
export CFLAGS=-m64
export CXXFLAGS=-m64
./configure --prefix=/home/usuario/libsmodels
sudo make
sudo make check
sudo make install
```

Instale o *Curl 7.50.3* (*http://curl.haxx.se/download.html*). Baixe-o, descompacte na pasta */home/usuario/libsmodels* e entre na pasta do *Curl* digite:

```
export F77=gfortran
export FC=gfortran
export CC=gcc
export CXX=g++
export FFLAGS="-m64 -fdefault-integer-8"
export FCFLAGS="-m64 -fdefault-integer-8"
export CFLAGS=-m64
export CXXFLAGS=-m64
./configure --prefix=/home/usuario/libsmodels/
sudo make
sudo make check
sudo make install
```

Instale as bibliotecas necessárias para usar o HDF5. Digite:

```
sudo apt-get install libgtk2.0-dev
```

Instale o *HDF5 1.8.9* (*https://www.hdfgroup.org/HDF5/release/obtain5.html*). Baixe-o, descompacte na pasta */home/usuario/libsmodels* e entre, via terminal, na pasta do *HDF5* digite:

```
export FC=gfortran
export CC=gcc
export CXX=g++
export LDFLAGS=-L/home/usuario/libsmodels/lib
export CPPFLAGS=-I/home/usuario/libsmodels/include
```

No mesmo diretório, digite:

```
./configure --enable-fortran=yes --enable-fortran2003=yes --enable-cxx=yes
--with-szlib=/home/usuario/libsmodels --with-zlib=/home/usuario/libsmodels --enable-hl
--enable-shared --prefix=/home/usuario/libsmodels
```

Complete a instalação do *HDF5* com os comandos abaixo:

```
sudo make
sudo make check
sudo make install
```

O próximo passo é instalar o *NetCDF-C 4.4.1* (*https://www.unidata.ucar.edu/downloads/netcdf/index.jsp*). Baixe-o, descompacte na pasta */home/usuario/libsmodels* e na pasta do *NetCDF-C* digite:

```
export FC=gfortran
export CC=gcc
export CXX=g++
export LDFLAGS=-L/home/usuario/libsmodels/lib
export CPPFLAGS=-I/home/usuario/libsmodels/include
```

Na mesma linha de comando, digite:

```
./configure --prefix=/home/usuario/libsmodels --enable-netcdf4 --enable-shared --enable-dap
--with-hdf5=/home/usuario/libsmodels
```

Complete a instalação do *NetCDF-C* com os comandos abaixo:

```
sudo make
sudo make check
sudo make install
```

Instale agora o *NetCDF-Fortran 4.2* (*https://www.unidata.ucar.edu/downloads/netcdf/index.jsp*). Baixe-o, descompacte na pasta */home/usuario/libsmodels* e na pasta do *NetCDF-Fortran* digite:

```
export FC=gfortran
export F77=gfortran
export CC=gcc
export CXX=g++
export LDFLAGS=-L/home/usuario/libsmodels/lib
export CPPFLAGS=-I/home/usuario/libsmodels/include
export LIBS='-lnetcdf -lhdf5 -lhdf5_hl -lz'
```

Na mesma linha de comando, digite:

```
./configure --prefix=/home/usuario/libsmodels --enable-netcdf4 --enable-shared
--with-hdf5=/home/usuario/libsmodels --enable-dap
```

Termine a instalação do *NetCDF-Fortran*:

```
sudo make
sudo make check
sudo make install
```

Instale o *JasPer 1.900.1* (*http://www.linuxfromscratch.org/blfs/view/svn/general/jasper.html*). Baixe-o, descompacte na pasta */home/usuario/libsmodels* e na pasta do JasPer digite:

```
export FC=gfortran
export F77=gfortran
export CC=gcc
export CXX=g++
./configure --prefix=/home/usuario/libsmodels
sudo make
sudo make check
sudo make install
```

Instale o *libpng 1.6.24* (*http://sourceforge.net/projects/libpng/?source=typ_redirect*). Baixe-o, descompacte na pasta */home/usuario/libsmodels* e na pasta do *libpng* digite:

```
export FC=gfortran
export F77=gfortran
export CC=gcc
export CXX=g++
export LDFLAGS=-L/home/usuario/libsmodels/lib
export CPPFLAGS=-I/home/usuario/libsmodels/include
export LIBS='-lz'
./configure --with-zlib=/home/usuario/libsmodels --prefix=/home/usuario/libsmodels
sudo make
sudo make check
sudo make install
```

Instale o *Udunits 2.1.24* (*ftp://ftp.unidata.ucar.edu/pub/udunits/*). Baixe-o, descompacte na pasta */home/usuario/libsmodels* e entre na pasta do *Udunits* digite:

```
export FC=gfortran
export F77=gfortran
export CC=gcc
export CXX=g++
./configure --prefix=/home/usuario/libsmodels
sudo make
sudo make check
sudo make install
```

Instale o NetCDF4 para Python. Neste caso, baixe primeiramente o Git e use-o para baixar.

```
sudo apt-get install git
```

Clone o repositório do *NetCDF4-Python* com o comando:

```
git clone https://github.com/Unidata/netcdf4-python
```

Entre na pasta do NetCDF4-Python e modifique o arquivo *setup.cfg.template* e salve:

```
ncconfig    = /home/usuario/libsmodels/bin/nc-config
netCDF4_dir = /home/usuario/libsmodels
HDF5_dir    = /home/usuario/libsmodels
szip_dir    = /home/usuario/libsmodels
jpeg_dir    = /home/usuario/libsmodels
curl_dir    = /home/usuario/libsmodels
```

Modifique o nome do arquivo *setup.cfg.template* para setup.cfg:

```
mv setup.cfg.template setup.cfg
```

Crie na pasta *libsmodels*, as subpastas *lib/python2.7/site-packages*:

```
mkdir lib
cd lib
mkdir python2.7
cd python2.7
mkdir site-packages
```

Volte para a pasta principal do *NetCDF4-Python* e compile:

```
python setup.py build
python setup.py install --prefix=/home/usario/libsmodels
```

Caso queira conferir se a instalação ocorreu com sucesso, tente importar a biblioteca no Python. Digite no terminal:

```
python
import netCDF4
```

Instale agora o *mpi4py* (*https://pypi.python.org/pypi/mpi4py*), extraia e digite:

```
python setup.py build
python setup.py install --prefix=/home/usuario/libsmodels
```

Para testar a instalação, digite:

```
mpiexec -n 5 python demo/helloworld.py
```

Instale agora o *ESMF* e *ESMPy* (*https://www.earthsystemcog.org/projects/esmpy/releases*). Primeiro digite os comandos a seguir para instalar os arquivos de bibliotecas necessárias:

```
sudo apt-get install python-setuptools
sudo easy_install pip
sudo pip install distribute
sudo pip install nose
```

Dentro da pasta do ESMF, digite no terminal:

```
export ESMF_F90COMPILER=gfortran
export ESMF_NETCDF_LIBS="-lnetcdff -lnetcdf"
export ESMF_DIR=/home/usuario/libsmodels/packages/esmp.ESMF_6_3_0rp1_ESMP_01/esmf
export ESMF_NETCDF="local"
export ESMF_COMPILER=gfortran
export ESMF_COMM=openmpi
export ESMF_TESTEXHAUSTIVE=on
export ESMF_TESTSHAREDOBJ=on
export ESMF_NETCDF_INCLUDE=/home/usuario/libsmodels/include
export ESMF_NETCDF_LIBPATH=/home/usuario/libsmodels/lib
export ESMF_INSTALL_PREFIX=/home/usuario/libsmodels/ESMF
make
make check
make all_tests
make install
```

Entre na pasta *scr/addon/ESMPy*:

```
cd src/addon/ESMPy/
```

Na mesma linha de comando, digite:

```
python setup.py build
--ESMFMKFILE=/home/usuario/libsmodels/ESMF/lib/libO/Linux.gfortran.64.openmpi.default/esmf.mk
```

Complete a instalação:

```
python setup.py install --prefix=/home/usuario/libsmodels
python setup.py test
```

Instale o Octant, utilizando o Git:

```
git clone https://github.com/hetland/octant
```

Na pasta *octant/external*, exclua tudo e baixe os seguintes arquivos:

```
rm -rf *
git clone https://github.com/sakov/gridgen-c.git
git clone https://github.com/sakov/gridutils-c
git clone https://github.com/sakov/csa-c
git clone https://github.com/sakov/nn-c
```

Renomeie as pastas para, respectivamente: *gridgen*, *gridutils*, *csa* e *nn*. Entre na pasta *nn/nn*, exporte as bibliotecas e instale o *nn*:

```
cd nn/nn/
export FC=gfortran
export F77=gfortran
export CC=gcc
export CXX=g++
./configure --prefix=/home/usuario/libsmodels
make
make install
```

Instale o *csa* da mesma maneira que foi instalado o nn:

```
cd ../../csa/csa/
export FC=gfortran
export F77=gfortran
export CC=gcc
export CXX=g++
./configure --prefix=/home/usuario/libsmodels
make
make install
```

Ainda na pasta do *csa*, copie o arquivo *csa.o* para a pasta */home/usuario/libsmodels/lib*:

```
cp csa.o /home/usuario/libsmodels/lib
```

Instale o *gridutils*:

```
cd ../../gridutils/gridutils/
export FC=gfortran
export F77=gfortran
export CC=gcc
export CXX=g++
LDFLAGS=-L/home/usuario/libsmodels/lib
./configure --prefix=/home/usuario/libsmodels CPPFLAGS=-I/home/usuario/libsmodels/include
make
make install
```

Instale o *gridgen*:

```
cd ../../gridgen/
export FC=gfortran
export F77=gfortran
export CC=gcc
export CXX=g++
LDFLAGS=-L/home/usuario/libsmodels/lib
./configure -prefix=/home/usuario/libsmodels CPPFLAGS=-I/home/usuario/libsmodels/include
```

Abra o arquivo *makefile* e altere no arquivo de acordo com o que está abaixo:

```
CFLAGS = -g -O2 -Wall -I/home/usuario/libsmodels/include
LDFLAGS = -L/home/usuario/libsmodels/lib
LIBS = -lgu -lm -L/home/usuario/libsmodels/lib
```

Salve o arquivo, feche e digite no terminal:

```
make
make lib
make shlib
make install
```

Dentro da pasta */home/usuario/libsmodels/octant/octant*, modifique o arquivo *grid.py* como o exemplo abaixo (aproximadamente na linha 898).

ATENÇÃO Observe atentamente a indentação do Python dentro dos arquivos!

```
self._libgridgen = np.ctypeslib.load_library('libgridgen.so', '/home/usuario/libsmodels/lib')
print octant.__path__[0]
self._libgridgen = np.ctypeslib.load_library('_gridgen', octant.__path__[0])
```

Salve e feche o arquivo. Digite:

```
python setup.py build --fcompiler=gfortran
```

Em */home/usuario/libsmodels/octant/octant*, abra o arquivo *csa.py* e modifique como abaixo:

```
_csa = np.ctypeslib.load_library('csa.o', '/home/usuario/libsmodels/libs')
```

Por fim, em */home/usuario/libsmodels/octant*, digite:

```
python setup.py install --prefix=/home/usuario/pythonmodels/octant
```

Exporte os diretórios no *.bashrc*. Lembre-se: o *.bashrc* encontra-se na sua */home/usuario*.

```
export PYTHONPATH=$PYTHONPATH:/home/usuario/libmodels/octant
export PYTHONPATH=$PYTHONPATH:/home/usuario/libmodels/octant/include
export PYTHONPATH=$PYTHONPATH:/home/usuario/libmodels/octant/lib/python2.7/site-packages
export PYTHONPATH=$PYTHONPATH:/home/usuario/libmodels/octant/lib
```

Atualize o *.bashrc* do terminal. Digite:

```
source .bashrc
```

5.1.2 Instalando com o Conda

O Anaconda, é uma distribuição para Python e R que fornece suporte a várias bibliotecas e pacotes utilizados neste guia, facilitando a instalação. Para baixar o Anaconda acesse: *https://www.continuum.io/downloads*. Para instalar basta entrar no diretório onde está o arquivo de instalação, mudar as permissões de instalação do arquivo e seguir as instruções do instalador:

```
sudo chmod 770 Anaconda2.sh
 ./Anaconda2.sh
```

A seguir, digite os seguintes comandos no terminal para instalar as bibliotecas necessários para construir um projeto no ROMS usando o Python:

```
conda install -c conda-forge openmpi
conda install -c anaconda gcc
conda install -c mutirri szip
conda install -c anaconda zlib
conda install -c anaconda curl
conda install -c anaconda hdf5
conda install -c conda-forge netcdf-fortran
conda install -c scitools jasper
conda install -c anaconda libpng
conda install -c conda-forge udunits
conda install -c anaconda netcdf4
conda install -c anaconda cython
conda install -c anaconda numpy
conda install -c anaconda scipy
conda install -c anaconda mpi4py
conda install -c conda-forge esmf
```

5.2 Instalando o Pyroms

Com as bibliotecas básicas já instaladas, nesta seção será mostrado como instalar o PYROMS. Ele é uma coleção de ferramentas para ajudar com arquivos de entrada e saída do ROMS. Foi originalmente iniciado por Rob Hetland como um projeto no GoogleCode e reescrito por Frederic Castruccio. Será seguido o mesmo esquema da seção anterior, com o endereço para baixar a biblioteca e os comandos que deverão ser digitados no terminal.

Baixe o PyROMS dentro do seu *libsmodels*:

```
git clone https://github.com/ESMG/pyroms.git
```

Por fim, entre no diretório */home/usuario/libsmodels/pyroms/pyroms_toolbox*, digite.

```
export FC=gfortran
export F77=gfortran
export CC=gcc
export CXX=g++
python setup.py build --fcompiler=gfortran
python setup.py install --prefix=/home/usuario/libsmodels/pyroms
```

Instale o bathy_smoother:

```
cd ../bathy_smoother/external/lp_solve_5.5/lp_solve/
sh ccc
cp bin/ux64/lp_solve /home/usuario/libsmodels/bin/
cd ../lpsolve55
sh ccc
cp bin/ux64/* /home/usuario/libsmodels/lib/
```

Entre no diretório a seguir e abra o *setup.py*:

```
cd ../../lp_solve_5.5/extra/Python/
gedit setup.py
```

Mude os caminhos descritos abaixo no arquivo *setup.py*. Lembre-se da indentação.

```
include_dirs=['../..','/usr/include','/home/usuario/libsmodels/include'],
library_dirs=['/home/usuario/libsmodels/pyroms/lib/','/home/usuario/libsmodels/lib'],
```

Instale:

```
python setup.py build
python setup.py install --prefix=/home/usuario/libsmodels/pyroms
```

Entre no diretório do bathy_smoother, como exemplificado abaixo e digite no terminal:

```
cd ../../../../../bathy_smoother/
export FC=gfortran
export F77=gfortran
export CC=gcc
export CXX=g++
python setup.py build --fcompiler=gfortran
python setup.py install --prefix=/home/usuario/libsmodels/pyroms
```

Instale o Pyroms. Para isso use o comando para alterar o diretório:

```
cd ../pyroms/pyroms/
```

Abra o arquivo *hgrid.py* e mude na linha 1028 como abaixo:

```
self._libgridgen = np.ctypeslib.load_library('libgridgen.so', '/home/usuario/libsmodels/lib')
```

Ainda no arquivo *hgrid.py*, adicione a seguinte biblioteca na linha 21:

```
from numpy import amin
```

Salve, feche o *hgrid.py* e digite:

```
cd ../
export FC=gfortran
export F77=gfortran
export CC=gcc
export CXX=g++
python setup.py build --fcompiler=gfortran
python setup.py install --prefix=/home/usuario/libsmodels/pyroms
```

Coloque os caminhos no seu *.bashrc*:

```
export PYTHONPATH=$PYTHONPATH:/home/usuario/libsmodels/pyroms/lib/python2.7/site-packages
export PYTHONPATH=$PYTHONPATH:/home/usuario/libsmodels/pyroms/lib/python2.7/site-packages
export PYTHONPATH=$PYTHONPATH:/home/usuario/libsmodels/pyroms/lib/python2.7/site-packages
export PYTHONPATH=$PYTHONPATH:/home/usuario/libsmodels/pyroms/lib
export PYTHONPATH=$PYTHONPATH:/home/usuario/libsmodels/pyroms/lib/python2.7/site-packages/pyroms_toolbox/Grid_HYCOM
export PYTHONPATH=$PYTHONPATH:/home/usuario/libsmodels/pyroms/examples
```

Atualize o *.bashrc*:

```
source .bashrc
```

Vá até */home/usuario/libsmodels/pyroms/lib/python2.7/site-packages/bathy_smoother/* e apague o arquivo lpsolve55.so.

Por fim, vá na pasta agora do *pyroms_toolbox/* e abra o *__init__.py* e comente a linha que importa *from move_river_t import move_river_t* (linha 51), depois na pasta *Grid_HYCOM* no arquivo *flood_fast.py* e comente na linha 9 o *import creep*.

Salve e tente importar o pyroms_toolbox:

```
python
import pyroms_toolbox
```

5.3 *model2roms*

Nesta seção será mostrado como instalar o model2roms, programa utilizado para gerar as condições e grade do ROMS. O *model2roms* é composto por vários códigos para criação dos arquivos de entrada do ROMS. Foi originalmente iniciado por Trond Kristiansen (Kristiansen, 2019) e foi adaptado para as necessidades do LOA-INPE. Será seguido o mesmo esquema da seção anterior, com o endereço para baixar a biblioteca e os comandos que deverão ser digitados no terminal.

Para baixar o *model2roms*, entre na *home* do seu computador e baixe o *model2roms* utilizando o Github:

```
cd /home/usuario
git clone https://github.com/usutil/model2roms
```

Altere o nome da pasta de *model2roms-master* para *model2roms*:

```
mv model2roms-master model2roms
```

5.3.1 Introdução sobre a grade do ROMS

Para gerar a grade do ROMS, usaremos o código *make_roms_grid.py*, localizado no diretório *model2roms/grid*. O código oferece suporte aos dados do SRTM30_plus (Becker et al., 2009), porém, para fins práticos, exemplificaremos apenas os dados do ETOPO1, que será discutido na próxima subseção.

Caso seja necessário, instale o basemap para utilizar o código:

```
conda install -c anaconda basemap
```

5.3.2 ETOPO1 1 Arc-Minute Global Relief Model

O ETOPO1 (Amante & Eakins, 2009; Figura 5.1) é produzido pelo National Geophysical Data Center e fornece duas camadas de informações de relevo. As camadas incluem batimetria sobre os oceanos e alguns dos principais lagos da Terra. A topografia terrestre e a batimetria oceânica baseiam-se na topografia SRTM30 e através de vários cruzeiros batimétricos.

Acesse o site: *https://www.ngdc.noaa.gov/mgg/global/global.html*.

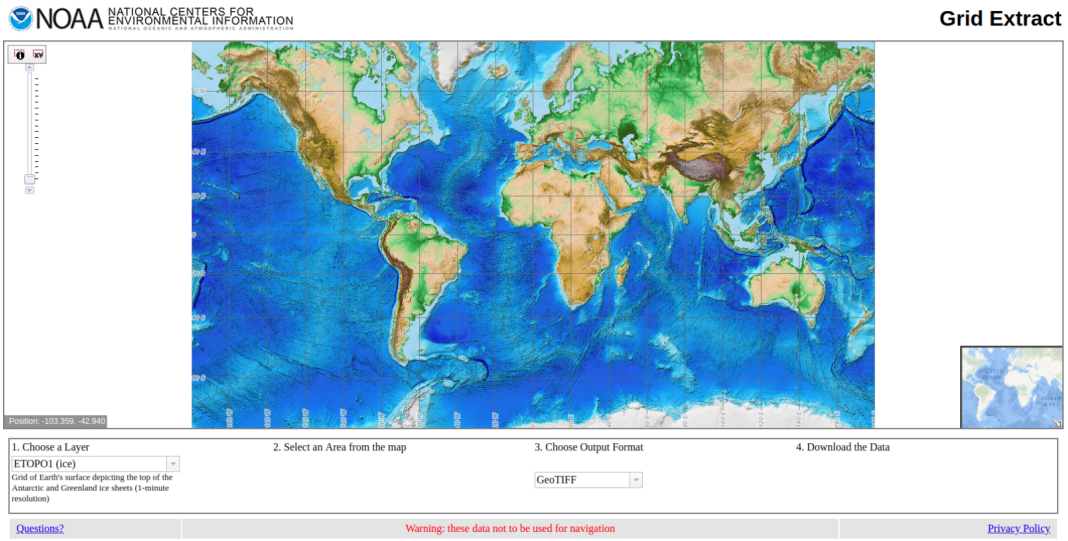

Figure 5.1. Apresentação do site do ETOPO1.

Delimite no mapa do site do ETOPO1 a sua área de interesse e baixe os dados no formato NetCDF.

> **ATENÇÃO** O código *make_roms_grid.py* não permite a seleção dos limites de latitude e longitude da grade, portanto, ao baixar os dados do ETOPO1, seja o mais preciso possível no recorte da sua área.

Gerando a grade do ROMS

Entre no diretório do *model2roms* e procure pela subpasta *grid*. Abra o código *make_roms_grid.py*.

```
cd /home/usuario/model2roms/grid
gedit make_roms_grid.py
```

Conforme a Figura 5.2, as variáveis que serão modificadas são:

- **grd_name**: Nome da grade;
- **grd_final**: O nome do arquivo NetCDF da grade;

- **etopo1_dir**: O diretório onde está localizado o arquivo NetCDF do ETOPO1;
- **srtm_dir**: O diretório onde está localizado o arquivo NetCDF do SRTM_30_PLUS;
- **hmin**: Valor mínimo de h;
- **theta_b**: Parâmetro de controle das coordenadas próximas ao fundo oceânico;
- **theta_s**: Parâmetro de controle das coordenadas próximas à superfície;
- **Tcline**: Profundidade crítica, em metros, controlando o alongamento das coordenadas seguidoras do terreno. Pode ser interpretado como a largura da superfície onde a resolução vertical é melhor;
- **N**: Número de camadas Sigma;
- **rmax**: Fator de suavização da topografia;
- **intrp_method**: Método de interpolação da grade: Interpolação linear (*linear*) ou por Vizinho Próximo (*nn*);
- **grid_resolution**: Resolução da grade;
- **max_depth**: Profundidade máxima da grade.

ATENÇÃO Em *grid_resolution*, é necessário colocar o numerador para fazer o cálculo do ETOPO1. Por exemplo: como o ETOPO1 possui 1/60° de resolução espacial, caso a resolução espacial escolhida seja de 1/12°, o valor de *grid_resolution* será 5, pois 5/60° será 1/12°.

ATENÇÃO Como não utilizaremos os dados do SRTM_30_PLUS, a variável *srtm_dir* não precisa ser modificada.

```
"""
File name:      make_roms_grid.py
Author:         Ueslei Adriano Sutil
Email:          uesleisutil@gmail.com
Created:        17 June 2016
Last modified: 04 July 2019
Version:        6.1

Variable options:
    - grd_name          As mentioned in gridid.txt Pyroms file;
    - intrp_method      'linear' or 'nn' for nearest neighborhood;
    - grid_resolution   The ETOPO1 spatial resolution is 1/60°. If you desire a 1/12° spatial resolution, enter 5 (5/60 = 1/12°);
                        The SRTM30+ spatial resolution is 1/120°. If you desire a 1/12° spatial resolution, enter 10 (10/120 = 1/12°).
    - max_depth         The grid max depth (m).

Download ETOPO1 here:
    https://rda.ucar.edu/datasets/ds759.4/index.html#!description
Reference:
    Amante, C. and B. W. Eakins, 2009: ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. 24, NOAA Technical Memorandum NESDIS NGDC, 19 pp.

Download SRTM30_plus here:
    https://topex.ucsd.edu/WWW_html/srtm30_plus.html
Reference:
    Becker, J. J., D. T. Sandwell, W. H. F. Smith, J. Braud, B. Binder, J. Depner, D. Fabre, J. Factor, S. Ingalls, S-H. Kim, R. Ladner, K. Marks, S. Nelson, A. Pharaoh, R. Trimmer, J. Von Rosenberg, G. Wallace, P. Weatherall., Global Bathymetry
"""

from   mpl_toolkits.basemap import Basemap
from   bathy_smoother       import bathy_tools, bathy_smoothing
import mpl_toolkits.basemap as mp
import numpy                as np
import netCDF4
import pyroms
import pyroms_toolbox

# Outputs names.
grd_name            = 'antartic'
grd_final           = grd_name+'_grd.nc'
etopo1_dir          = '/home/usuario/model2roms/grid/etopo1.nc'
srtm_dir            = '/home/usuario/model2roms/grid/topo30.nc'

# Grid settings.
hmin                = 25
theta_b             = 2.0
theta_s             = 7.0
Tcline              = 200
N                   = 40
rmax                = 0.25
intrp_method        = 'linear'
grid_resolution     = 5
max_depth           = -5000


# NOTE: Do not need to change above.

# Open bathymetry file.
print("Choose the Digital Elevation Model: (1) ETOPO1 or (2) SRTM30+, then press the [ENTER] buttom:")
grid_choice = input()
if grid_choice=="1":
    data = netCDF4.Dataset(etopo1_dir, 'r')
    lons = data.variables[u'x'][:]
    lats = data.variables[u'y'][:]
    cota = data.variables[u'z'][:]
    cota = np.array(cota, dtype='float32')
elif grid_choice=="2":
```

Figure 5.2. Captura de tela do código *make_grid.py*, que se encontra dentro da pasta *model2roms/grid*.

Após realizar as modificações, basta apenas executar o código. Digite:

```
ipython make_roms_grid.py --pylab
```

5.3.3 Introdução sobre as condições do ROMS

Utilizaremos o *model2roms* para gerar as condições do ROMS. A toolbox oferece suporte aos dados do GLORYS12V1 (Fernandez & Lellouche, 2018) e SODA3 (Carton et al., 2009), porém, utilizaremos apenas o GLORYS12V1 como exemplo.

5.3.4 Global Ocean Physics Reanalysis (GLORYS)

O GLORYS é uma reanálise global do oceano com resolução espacial de 1/12°, resolução temporal diária ou mensal e 50 níveis verticais. Ele é baseado no atual sistema CMEMS de previsão global do tempo e é forçado pelo ERA-Interim do ECMWF a partir do modelo NEMO. É utilizado um filtro de Kalman de ordem reduzida para assimilar os dados de altimetria do mar, temperatura da superfície do mar, concentração de gelo marinho obtidos a partir de sensoriamento remoto e os dados *in situ* de perfis verticais de temperatura e salinidade. Além disso, um esquema 3D-VAR fornece uma correção para os desvios de temperatura e salinidade.

O GLORYS pode ser baixado no site: *http://marine.copernicus.eu/services-portfolio/access-to-products/?option=com_csw&view=details&product_id=GLOBAL_REANALYSIS_PHY_001_030*.

Ao tentar baixar, o site avisará que será necessário criar uma conta no Copernicus. Faça o cadastro e escolha o conjunto de dados diários do GLORYS, conforme a Figura 5.3.

Figure 5.3. Captura de tela do site do GLORYS.

Clique em *Dowload product* e, na próxima página (Figura 5.4), selecione a área conforme os limites de latitude e longitude da grade escolhida. Também escolha o período dos dados que serão baixados e caso pretenda utilizar o modelo de gelo marinho no ROMS, selecione todas as variáveis, com excessão de:

- *bottomT - Sea floor potential temperature*;
- *mlotst - Density ocean mixed layer thickness*.

Caso escolha não utilizar o modelo de gelo marinho, não selecione as variáveis:

- *siconc - Ice concentration*;
- *sithick - Sea ice thickness*;
- *usi - Sea ice eastward velocity*;
- *vsi - Sea ice northward velocity*.

Figure 5.4. Captura de tela do site do GLORYS.

O servidor do Copernicus libera para download arquivos com no máximo 1024 mb. Caso o período selecionado apresente um tamanho de arquivo maior, como por exemplo na Figura 5.5, será necessário retornar ao passo anterior e particionar os arquivos em datas menores ou então baixar o arquivo completo clicando em *FTP ACCESS* (Figura 5.5)

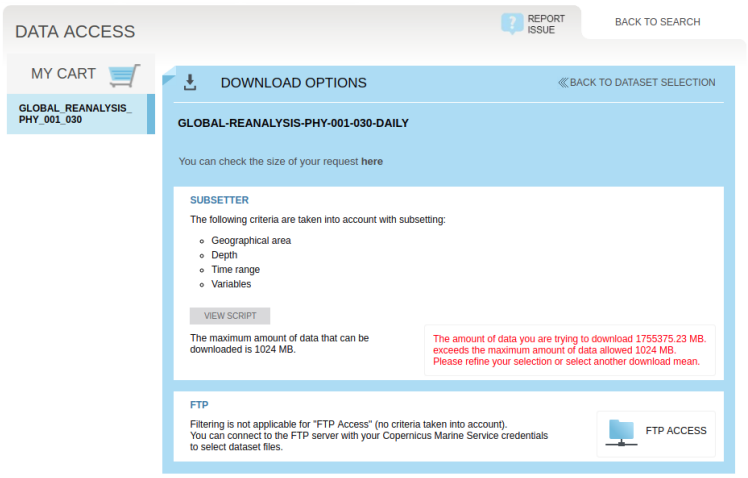

Figure 5.5. Mensagem de erro ao tentar realizar o *download* de um arquivo maior que 1024 mb.

Caso opte por particionar as datas ou baixar os arquivos por *FTP*, será necessário criar um novo arquivo com todas as datas escolhidas concatenadas. Neste caso, é necessário utilizar o *Climate Data Operators* (CDO).

Existem duas maneiras de instalar o CDO: pelo *Conda* ou por *apt-get*.

Pelo *Conda*, digite:

```
conda install -c conda-forge cdo
```

Por *apt-get*:

```
sudo apt-get install cdo
```

Após a instalação, entre no diretório onde estão localizados todos os arquivos do GLORYS e digite:

```
cdo cat glorys* glorys.nc
```

Onde:

- *cdo* significa o comando do programa;
- *cat* a concatenação de todos os arquivos;
- *glorys** que serão concatenados todos os arquvis chamados *glorys* dentro da pasta;
- *glorys.nc* o arquivo final criado pela concatenação do *CDO*.

ATENÇÃO Para facilitar os próximos passos, coloque o arquivo do GLORYS dentro do diretório */home/usuario/model2roms/input*

5.3.5 Gerando as condições do ROMS

Ao abrir a pasta do *model2roms* é possível observar diversos códigos. Começaremos com o código o *compile.py*, que compilará diversos arquivos em linguagem Fortran90 para Python.

Compile os arquivos com o comando:

```
ipython compile.py --pylab
```

Caso o nome do seu arquivo do *GLORYS* seja diferente de *glorys.nc*, abra o código *forcingFilenames.py* (Figura 5.6) e na linha 15, altere *'glorys.nc'* para o nome do arquivo criado.

```
cd /home/usuario/model2roms
gedit forcingFilenames.py
```

```
import os

# Main function called from model2roms
def getFilename(confM2R,year,month,defaultvar):
    if confM2R.indatatype == 'SODA3':
        if defaultvar is None:defaultvar="salinity"
        filenamein = getSODA3filename(confM2R, year, month, defaultvar)
    if confM2R.indatatype == 'GLORYS':
        if defaultvar is None:defaultvar="temperature"
        filenamein = getGLORYSfilename(confM2R, year, month, defaultvar)
    return filenamein

# private functions called from within module
def getGLORYSfilename(confM2R, year, month, myvar):
    filename = confM2R.modelpath + 'glorys.nc'

    return filename

def getSODA3filename(confM2R, year, month, myvar):
    if (myvar in ['cn', 'hi', 'hs']):
        return confM2R.modelpath + "soda3.3.1_mn_ice_reg_" + str(year) + ".nc"
    else:
        return confM2R.modelpath + "soda3.3.1_mn_ocean_reg_" + str(year) + ".nc"
```

Figure 5.6. Captura de tela do código *forcingFilename.py*.

Abra o arquivo *configM2R.py* e, na linha 16 (Figura 5.7), altere a abreviação *SuaAbreviaçãoAqui* da definição *defineabbreviation* para o nome de sua escolha.

```
# Define abbreviation for the run: sued to name output files etc.
def defineabbreviation(self):
    return {"SuaAbreviaçãoAqui": "SuaAbreviaçãoAqui"}[self.outgrid]
```

Figure 5.7. Captura de tela da definição *defineabbreviation* no código *configM2R.py*.

Na linha 63 (Figura 5.8), altere o diretório da grade *Minha_Grade.nc* para o diretório da grade escolhida e a abreviação *SuaAbreviaçãoAqui* pelo nome escolhido no passo anterior.

```
def defineromsgridpath(self):
    return {'SuaAbreviaçãoAqui': '/home/usuario/model2roms/grid/Minha_Grade.nc'}[self.outgrid]
```

Figure 5.8. Captura de tela do código *configM2R.py*.

Na linha 67 (Figura 5.9), altere o diretório do arquivo do *GLORYS* para o caminho escolhido.

```
def defineforcingdatapath(self):
    return {'SODA3': "/home/usuario/Documentos/model2roms/input/",
            'GLORYS': "/home/usuario/Documentos/model2roms/input/"}[self.indatatype]
```

Figure 5.9. Captura de tela do código *configM2R.py*.

A partir da linha 76 (Figura 5.10), modifique de acordo com o seu projeto:

- **self.compileall**: *True* caso deseje que os arquivos em Fortran sejam recompilados cada vez que o *model2roms* for executado;
- **self.createoceanforcing**: *True* para criar as variáveis oceânicas;
- **self.createatmosforcing**: *True* para criar as forçantes atmosféricas. **Atualmente esta função encontra-se em fase de testes e não está inteiramente disponível para uso**;
- **self.writeice**: *True* para criar as variáveis de gelo marinho.
- **self.set2DvarsToZero**: Cria os arquivos de gelo e altura do nível do mar com valores zerados. Como o GLORYS possui esses valores, é recomendado deixar *False*;
- **self.useesmf**: *True* para usar o *ESMF* para interpolar os dados do GLORYS para a grade do ROMS;
- **self.usefilter**: *True* para aplicar um filtro para suavizar os campos 2D.
- **self.myformat**: O formato para escrever os arquivos de entrada do ROMS. Por padrão *NETCDF*;
- **self.timefrequencyofinputdata**: A frequência dos dados de entrada. No caso do GLORYS, escrever *'day'*;
- **self.indatatype**: O nome do dado utilizado para gerar as condições. *'GLORYS* ou *SODA3*;
- **self.authorname**: O nome do usuário que está utilizando o *model2roms*;
- **self.authoremail**: O email do usuário que está utilizando o *model2roms*;
- **self.ingridtype**: Interpolará a grade do GLORYS, que é em coordenada *'ZLEVEL'*;
- **self.grdtype**: O tipo de grade do GLORYS, que é *'regular'*;
- **self.lonname**: O nome da variável de longitude do GLORYS, que é *'longitude'*;
- **self.latname**: O nome da variável de latitude do GLORYS, que é *'latitude'*;
- **self.depthname**: O nome da variável de profundidade do GLORYS, que é *'depth'*;
- **self.lonname_u**: O nome da variável de longitude em U do GLORYS, que é *'longitude'*;
- **self.latname_u**: O nome da variável de latitude em U do GLORYS, que é *'latitude'*;
- **self.lonname_v**: O nome da variável de longitude em V do GLORYS, que é *'longitude'*;
- **self.latname_v**: O nome da variável de latitude em V do GLORYS, que é *'latitude'*;
- **self.timename**: O nome da variável de tempo do GLORYS, que é *'time'*;
- **self.realm**: O ambiente em que está sendo executado o 'textitmodel2roms, neste caso, *'ocean'*;
- **self.fillvaluein**: O valor de *fillvalue* do arquivo NetCDF. Por definição, *-1.e20*;
- **self.outgrid**: O nome da abreviação utilizada na definição *defineabbreviation*;
- **self.outgridtype**: Se *"ROMS"*, criará as saídas no formato padrão do ROMS;
- **self.nlevels**: O número de níveis verticais da grade. Deverá ser o mesmo que o escolhido no código *make_roms_grid.py*;

- **self.vstretching**: Deverá ser o mesmo que o escolhido no código *make_roms_grid.py*;
- **self.vtransform**: Deverá ser o mesmo que o escolhido no código *make_roms_grid.py*;
- **self.theta_s**: Deverá ser o mesmo que o escolhido no código *make_roms_grid.py*;
- **self.theta_b**: Deverá ser o mesmo que o escolhido no código *make_roms_grid.py*.
- **self.tcline**: Deverá ser o mesmo que o escolhido no código *make_roms_grid.py*.
- **self.hc**: Deverá ser o mesmo que o escolhido no código *make_roms_grid.py*.
- **self.start_year**: O ano inicial dos dados do GLORYS;
- **self.end_year**: O ano final dos dados do GLORYS;
- **self.start_month**: O mês inicial dos dados do GLORYS;
- **self.end_month**: O mês final dos dados do GLORYS;
- **self.start_day**: O dia inicial dos dados do GLORYS;
- **self.end_day**: O dia final dos dados do GLORYS;

```
# Set compileAll to True if you want automatic re-compilation of all the
# fortran files necessary to run model2roms. Options are "gfortran" or "ifort". Edit
# compile.py to add other fortran compilers.
self.compileall = False
 # Create the bry, init, and clim files for a given grid and input data
self.createoceanforcing = True
# Create atmospheric forcing for the given grid
self.createatmosforcing = False  # currently in beta stages and unavailable
# Write ice values to file (for Arctic regions)
self.writeice = True
# ROMS sometimes requires input of ice and ssh, but if you dont have these write zero files to file
self.set2DvarsToZero= False
# Use ESMF for the interpolation. This requires that you have ESMF and ESMPy installed (import ESMF)
self.useesmf = True
# Apply filter to smooth the 2D fields after interpolation (time consuming but enhances results)
self.usefilter = True
# Format to write the ouput to: 'NETCDF4', 'NETCDF4_CLASSIC', 'NETCDF3_64BIT', or 'NETCDF3_CLASSIC'
# Using NETCDF4 automatically turns on compression of files (ZLIB)
self.myformat = 'NETCDF4'
self.myzlib = True
# Frequency of the input data: usually monthly
self.timefrequencyofinputdata = "day"  # , "month", "hour"
#  Define what grid type you wnat to interpolate from (input MODEL data)
# Options:
# 1. SODA3 or 2. GLORYS.
self.indatatype = 'GLORYS'
# Define contact info for final NetCDF files
self.authorname  = "Usuario"
self.authoremail = "nome.sobrenome (at) usuario.br"
# Define what grid type you want to interpolate from: Can be Z for SIGMA for ROMS
# vertical coordinate system or ZLEVEL. Also define the name of the dimensions in the input files.
# Options:
# 1. SIGMA (not prpoerly implemented yet), 2. ZLEVEL
self.ingridtype = "ZLEVEL"
# Define the names of the geographical variables in the input files
self.grdtype     = 'regular'
self.lonname     = "longitude"
self.latname     = "latitude"
self.depthname   = "depth"
self.lonname_u   = "longitude"
self.latname_u   = "latitude"
self.lonname_v   = "longitude"
self.latname_v   = "latitude"
self.timename    = "time"
self.realm       = "ocean"
self.fillvaluein = -1.e20
# Define what grid type you want to interpolate to
# Options: This is just the name of your grid used to identify your selection later
self.outgrid     = "antartic"
self.outgridtype = "ROMS"
# Define omber of output depth levels
self.nlevels     = 40
# Define the grid stretching properties (leave default if uncertain what to pick)
self.vstretching = 4
self.vtransform  = 2
self.theta_s     = 7.0
self.theta_b     = 2.0
self.tcline      = 200.0
self.hc          = 200
# Define the period to create forcing for
self.start_year  = 2015
self.end_year    = 2015
self.start_month = 10
self.end_month   = 11
self.start_day   = 1
self.end_day     = 31
```

Figure 5.10. Captura de tela do código *configM2R.py*.

Execute o *model2roms* com o comando:

```
ipython runM2R.py
```

Ao finalizar, serão criados os arquivos inicial, de fronteira e o climatológico que deverão ser adicionados na sua pasta de projetos, dentro da Kerana.

6. Building the SWAN

SWAN uses the *SWAN.EDT* file to read the grid (*swan_coord.grd*) and bathymetry (*swan_bathy.bot*) files. It is also possible to define a numerical grid within the *SWAN.EDT* and indicate the bathymetry file that will be read and associated with the defined grid.

As an example, SWAN files will be created from the ROMS grid, but without the introduction of initial data, as the implementation of a grid inside *SWAN.EDT* is not trivial.

For SWAN boundary conditions, the wind fields will come from the WRF, as soon as the waves generated are associated with the atmospheric systems represented in these simulations. Without the information the boundary files information, the simulated waves will be generated only within the boundary of the domain, disregarding the energy that is leaving or entering the grid.

We will use the MATLAB script, *make_swan.m*, to generate the files. The script is located at:

```
1 /home/name.surname/repositorio/SWAN_scripts
```

As shown in Figure 6.1, the script has the following construction:

```
clear all
ncfile   = '../roms_grid.nc'
x_rho    = ncread(ncfile,'lon_rho');
y_rho    = ncread(ncfile,'lat_rho');
h        = ncread(ncfile,'h');
mask_rho = ncread(ncfile,'mask_rho');

%Replace the land positions with the flag for land (defined in the SWAN
%input file)
land_values = find(mask_rho == 0);
h(land_values) = 9999;

%Print the depths to the bathy file
[n,m] = size(h);

fid = fopen('swan_bathy.bot','w');
for index1 = 1:m;
    for index2 = 1:n;
        fprintf(fid,'   ');
       fprintf(fid,'%12.8f',h(index2,index1));
    end
    fprintf(fid,'\n');
end

%Print the grid coordinates to the grid file
fid = fopen('swan_coord.grd','w');
fprintf(fid,'%12.6f\n',x_rho);
fprintf(fid,'%12.6f\n',y_rho);
```

Figure 6.1. *make_swan.m* script.

To generate the two SWAN files, look in the script for the variable *ncfile* and change the directory to the path where your ROMS grid is.

Run the script and the two files will be created: *swan_coord.grd* and *swan_bathy.bot*. The two files must be placed inside your project folder.

7. Building the Budgell's Sea Ice Model

The sea ice model is fully coupled to ROMS, so that, after generating the conditions of the ROMS with ice data (See Section 5.3), to activate the sea ice model just modify the ROMS *.h* file in your project. According to Hedström (2018), you can add the following options into the *.h* file, as shown in Figure 7.1:

- **ICE_MODEL**: defines the sea ice model;
- **ANA_ICE**: define condições iniciais analíticas para o gelo marinho;
- **ICE_THERMO**: defined the ice thermodynamics;
- **ICE_MK**: defined the Mellor & Kanta (1989) ice thermodynamics. Currently, is the only choice;
- **ICE_MOMENTUM**: defines the momentum component of the ice;
- **ICE_MOM_BULK**: defines the alternate ice-water stress computation;
- **ICE_EVP**: defines the elastic-viscous-plastic rheology from Hunke & Dukowicz (1997) and Hunke (2001);
- **ICE_QUAD_STRENGTH**: defines the quadratic ice strength from Overland & Pease (1988);
- **ICE_ADVECT**: defines the advection of ice tracers;
- **ICE_SMOLAR**: defines the MPDATA use for ice tracers. Currently, it is the only option;
- **ICE_UPWIND**: defines the upwind advection;
- **ICE_BULK_FLUXES**: define the ice part of bulk flux computation;
- **ICE_DIAGS**: defines the diagnosis of sea ice;
- **ICE_SHOREFAST** : define the simple shorefast-ice algorithm from Budgell (2005).
- **ICE_I_O**: define to allow light into the ice as heat;
- **ICE_CONVSNOW**: defines the conversion of flooded snow to ice.

```
#ifdef SOLVE3D
# define ICE_MODEL
# ifdef ICE_MODEL
#  define ANA_ICE
#  define ICE_THERMO
#  define ICE_MK
#  define ICE_MOMENTUM
#  define ICE_MOM_BULK
#  define ICE_EVP
#  define ICE_STRENGTH_QUAD
#  define ICE_ADVECT
#  define ICE_SMOLAR
#  define ICE_UPWIND
#  define ICE_BULK_FLUXES
#  define ICE_I_O
#  define ICE_DIAGS
# endif
#endif
```

Figure 7.1. Screenshot of ROMS *.h* file

For more information about the model, it is recommended to read Hedström (2018).

Get the *.in* file for the sea ice model. Copy the file *ice.in* into the Kerana repository and add it to your project.

```
/home/name.surname/repositorio/ICE_scripts
```

Modify the ROMS *.in* file, pointing to the *ice.in* into the variable *IPARNAM*:

```
nedit ocean.in
IPARNAM =  ice.in
```

8. Building the weights between grids with SCRIP

8.1 Building the weights

As seen in the section 1.6, SCRIP is used to interpolate the weights between two or more grids of different models. In COAWST, the package was modified to generate only one NetCDF file that will be used during integrations.

The SCRIP directory is located at:

```
/home/name.surname/COAWST/Lib/SCRIP
```

Inside the folder, look for the file with the extension.*in*. As in the example in Figure 8.1:

```
$INPUTS
!
!  Input file for scrip_coawst.
!  The $INPUTS line is required at the top of this file.
!  Edit this file to enter the correct information below.
!  Then run this program as "scrip_coawst scrip_coawst_sandy.in"
!
! 1) Enter name of output netcdf4 file
!
OUTPUT_NCFILE='scrip_sandy_moving.nc'
!OUTPUT_NCFILE='scrip_sandy_static.nc'

! 2) Enter total number of ROMS, SWAN, and WRF (max_dom) grids:
!
NGRIDS_ROMS=2,
NGRIDS_SWAN=2,
NGRIDS_WRF=2,

! 3) Enter name of the ROMS grid file(s):
!
ROMS_GRIDS(1)='/home/nome.sobrenome/COAWST/Projects/Sandy/Sandy_roms_grid.nc',
ROMS_GRIDS(2)='/home/nome.sobrenome/COAWST/Projects/Sandy/Sandy_roms_grid_ref3.nc',

! 4) Enter SWAN information:
!    -the name(s) of the SWAN grid file(s) for coords and bathy.
!    -the size of the SWAN grids, and
!    -if the swan grids are Spherical(set cartesian=0) or
!                           Cartesian(set cartesian=1).
!
SWAN_COORD(1)='/home/nome.sobrenome/COAWST/Projects/Sandy/Sandy_swan_coord.grd',
SWAN_COORD(2)='/home/nome.sobrenome/COAWST/Projects/Sandy/Sandy_swan_coord_ref3.grd',
SWAN_BATH(1)='/home/nome.sobrenome/COAWST/Projects/Sandy/Sandy_swan_bathy.bot',
SWAN_BATH(2)='/home/nome.sobrenome/COAWST/Projects/Sandy/Sandy_swan_bathy_ref3.bot',
SWAN_NUMX(1)=84,
SWAN_NUMX(2)=116,
SWAN_NUMY(1)=64,
SWAN_NUMY(2)=86,
CARTESIAN(1)=0,
CARTESIAN(2)=0,

! 5) Enter the name of the WRF input grid(s). If the grid is a
!    moving child nest then enter that grid name as 'moving'.
!    Also provide the grid ratio, this is used for a moving nest.
!
WRF_GRIDS(1)='/home/nome.sobrenome/COAWST/Projects/Sandy/wrfinput_d01',
!WRF_GRIDS(2)='/home/nome.sobrenome/COAWST/Projects/Sandy/wrfinput_d02',
WRF_GRIDS(2)='moving',
PARENT_GRID_RATIO(1)=1,
PARENT_GRID_RATIO(2)=3,
PARENT_ID(1)=0
PARENT_ID(2)=1

!
!  The $END statement below is required
```

Figure 8.1. SCRIP *.in* file for the Sandy project.

In *OUTPUT_NCFILE*, change the name of the NetCDF file that will be generated if necessary.

In section 2 of the file, change the variables *NGRIDS_ROMS*, *NGRIDS_SWAN* and *NGRIDS_WRF* according to the number of grids, existing in your project, in ROMS, SWAN and WRF, respectively.

In the third section of the file, renew the ROMS grid directories according to the names in your project.

For SWAN, in the fourth section, in addition to changing the directories of the SWAN grids (*SWAN_COORD* and *SWAN_BATH*), change the number of existing grid points, according to your project , in the variables *SWAN_NUMX* and *SWAN_NUMY*.

Finally, in the fifth section, change the WRF grid directories (*WRF_GRIDS*). In *PARENT_GRID_RATIO*, if your project includes nesting between the WRF grids, change to the relationship used between the grids used in your project. In *PARENT_ID*, add the grid ID.

Then, save the changes.

To run SCRIP, search the repository for the file *qsub_scrip.sh*:

```
1 /home/name.surname/repositorio/qsub_scrip.sh
```

Move the file to the SCRIP directory:

```
1 mv /home/name.surname/repositorio/qsub_scrip.sh /home/name.surname/COAWST/Lib/SCRIP
```

Open the file *qsub_scrip.sh*:

```
nedit qsub_scrip.sh
```

Change and save the file *.sh*, as in the example in Figure 8.2:

```
#!/bin/sh
#PBS -l mppwidth=1
#PBS -N SCRIP
#PBS -j oe
#PBS -o Joe_test.out
#PBS -l walltime=35600:00:00
#PBS -q workq
  echo "Running GEOGRID on KERANA"
#
  export MPICH_ENV_DISPLAY=1
  export MPICH_ABORT_ON_ERROR=1
  export MPICH_RANK_REORDER_DISPLAY=1
  export MPICH_RANK_REORDER_METHOD=1
  export MALLOC_MMAP_MAX_=0
  export MALLOC_TRIM_THRESHOLD_=536870912
  export OMP_NUM_THREADS=1
#
  EXECDIR=/scratch/nome.sobrenome/COAWST/Lib/SCRIP
  chmod 755 *
# export  ATP_ENABLED=1
# ulimit -a
# ulimit -c unlimited
# ulimit -s unlimited
# ulimit -m unlimited
# ulimit -a


 cd $EXECDIR

 aprun -n 1 scrip_coawst /scratch/nome.sobrenome/COAWST/Lib/SCRIP/scrip_coawst_sandy.in 1> log.out 2> log.err
```

Figure 8.2. *.sh* file used to run SCRIP.

To start SCRIP, type:

```
qsub qsub_scrip.sh
```

At the end, the file *scrip_static.nc* will be created. Now put them in your project folder and you're done! COAWST is ready to run.

8.2 Executing your project

Now, with everything ready, your project is ready to be executed. Visit the section 2.10 to remember how to execute the project.

9. Papers of the Ocean and Atmospheric Studies Laboratory

Ocean-Atmosphere Interactions in an Extratropical Cyclone in the Southwest Atlantic

U. A. Sutil, L. P. Pezzi, R. C. M. Alves and A. B. Nunes

Abstract

This work shows an investigation of the behavior of heat fluxes in the processes of ocean-atmosphere interaction during the passage of an Extra-tropical Cyclone (EC) in the Southwest Atlantic in September 2006 using a coupled regional model's system. A brief evaluation of the simulated data is done by comparison with air and sea surface temperature (SST) data, wind speed, sea level pressure. This comparison showed that both model simulations present some differences (mainly, the wind), nevertheless the simulated variables show quite satisfactory results, therefore allowing a good analysis of the ocean-atmosphere interaction processes. The simulated thermal gradient increases the ocean's heat fluxes into the atmosphere in the cold sector of the cyclone and through the convergence of low level winds the humidity is transported to higher levels producing precipitation. The coupled system showed a greater ability to simulate the intensity and trajectory of the cyclone, compared to the simulation of the atmospheric model.

U. A Sutil et al. (2018). "Ocean-Atmosphere Interactions in an Entratropical Cyclone in the Southwest Atlantic". In: *Anuário do Instituto de Geociências - UFRJ*, pp. 525–535. DOI: 10.11137/2019_1_525_535

Avaliable at: *http://www.anuario.igeo.ufrj.br/2019_01/2019_1_525_535.pdf*

Low connectivity compromises the conservation of reef fishes by marine protected areas in the tropical South Atlantic

C. A. K. Endo, D. F. M. Gherardi, L. P. Pezzi and L. N. Lima

Abstract

The total spatial coverage of Marine Protected Areas (MPAs) within the Brazilian Economic Exclusive Zone (EEZ) has recently achieved the quantitative requirement of the Aichii Biodiversity Target 11. However, the distribution of MPAs in the Brazilian EEZ is still unbalanced regarding the proportion of protected ecosystems, protection goals and management types. Moreover, the demographic connectivity between these MPAs and their effectiveness regarding the maintenance of biodiversity are still not comprehensively understood. An individual-based modeling scheme coupled with a regional hydrodynamic model of the ocean is used to determine the demographic connectivity of reef fishes based on the widespread genus Sparisoma found in the oceanic islands and on the Brazilian continental shelf between 10° N and 23° S. Model results indicate that MPAs are highly isolated due to extremely low demographic connectivity. Consequently, low connectivity and the long distances separating MPAs contribute to their isolation. Therefore, the current MPA design falls short of its goal of maintaining the demographic connectivity of Sparisoma populations living within these areas. In an extreme scenario in which the MPAs rely solely on protected populations for recruits, it is unlikely that they will be able to effectively contribute to the resilience of these populations or other reef fish species sharing the same dispersal abilities. Results also show that recruitment occurs elsewhere along the continental shelf indicating that the protection of areas larger than the current MPAs would enhance the network, maintain connectivity and contribute to the conservation of reef fishes.

C. A. K. Endo et al. (2019). "Low connectivity compromises the conservation of reef fishes by marine protected areas in the tropical South Atlantic". In: *Nature Scientific Reports*, pp. 01–11. DOI: 10.1038/s41598-019-45042-0

Avaliable at: *https://www.nature.com/articles/s41598-019-45042-0*

An Investigation of Ocean Model Uncertainties Through Ensemble Forecast Experiments in the Southwest Atlantic Ocean

L. N. Lima, L. P. Pezzi, S. G. Penny and C. A. S. Tanajura

Abstract

Ocean general circulation models even with realistic behavior still incorporate large uncertainties from external forcing. This study involves the realization of ensemble experiments using a regional model configured for the Southwest Atlantic Ocean to investigate uncertainties derived from the external forcing such as the atmosphere and bathymetry. The investigation is based on perturbing atmospheric surface fluxes and bathymetry through a series of ensemble experiments. The results showed a strong influence of the South Atlantic Convergence Zone on the underlying ocean, 7 days after initialization. In this ocean region, precipitation and radiation flux perturbations notably impacted the sea surface salinity and sea surface temperature, by producing values of ensemble spread that exceeded 0.08 and 0.2 °C, respectively. Wind perturbations extended the impact on currents at surface, with the spread exceeding 0.1 m/s. The ocean responded faster to the bathymetric perturbations especially in shallow waters, where the dynamics are largely dominated by barotropic processes. Ensemble spread was the largest within the thermocline layer and in ocean frontal regions after a few months, but by this time, the impact on the modeled ocean obtained from either atmospheric or bathymetric perturbations was quite similar, with the internal dynamics dominating over time. In the vertical, the sea surface temperature exhibited high correlation with the subsurface temperature of the shallowest model levels within the mixed layer. Horizontal error correlations exhibited strong flow dependence at specific points on the Brazil and Malvinas Currents. This analysis will be the basis for future experiments using ensemble-based data assimilation in the Southwest Atlantic Ocean.

L. N. Lima et al. (2019). "An Investigation of Ocean Model Uncertainties Through Ensemble Forecast Experiments in the Southwest Atlantic Ocean". In: *Journal of Geophysical Research: Oceans* 120, pp. 432–452

Avaliable at: *hhttps://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2018JC013919*

Coupled ocean-atmosphere forecasting at short and medium time scales

J. Pullen, R. Allard, H. Seo, A. J. Miller, S. Chen, L. P. Pezzi, T. Smith, P. Chu, J. Alves and R. Caldeira

Abstract

Recent technological advances over the past few decades have enabled the development of fully coupled atmosphere-ocean modeling prediction systems which are used today to support short-term (days to weeks) and medium-term (10-21 days) needs for both the operational and research communities. Utilizing several coupled modeling systems we overview the coupling framework, including model components and grid resolution considerations, as well as the coupling physics by examining heat fluxes between atmosphere and ocean, momentum transfer, and freshwater fluxes. These modeling systems can be run as fully coupled atmosphere-ocean and atmosphere-ocean-wave configurations. Examples of several modeling systems applied to complex coastal regions including Madeira Island, Adriatic Sea, Coastal California, Gulf of Mexico, Brazil, and the Maritime Continent are presented. In many of these studies, a variety of field campaigns have contributed to a better understanding of the underlying physics associated with the atmosphere-ocean feedbacks. Examples of improvements in predictive skill when run in coupled mode versus standalone are shown. Coupled model challenges such as model initialization, data assimilation, and earth system prediction are discussed.

J. Pullen et al. (2017). *The Science of Ocean Prediction, The Sea*. P. Lermusiaux and K. Brink. Chap. Coupled ocean-atmosphere modeling and predictions

Avaliable at: *http://meteora.ucsd.edu/∼miller/papers/TheSea_Chapter23.html*

Regional modeling of the water masses and circulation annual variability at the Southern Brazilian Continental Shelf

L. F. Mendonça, R. B. Souza, C. R. C. Aseff, L. P. Pezzi, O. O. Möller and R. C. M. Alves

Abstract

The Southern Brazilian Continental Shelf (SBCS) is one of the more productive areas for fisheries in Brazilian waters. The water masses and the dynamical processes of the region present a very seasonal behavior that imprint strong effects in the ecosystem and the weather of the area and its vicinity. This paper makes use of the Regional Ocean Modeling System (ROMS) for studying the water mass distribution and circulation variability in the SBCS during the year of 2012. Model outputs were compared to in situ, historical observations and to satellite data. The model was able to reproduce the main thermohaline characteristics of the waters dominating the SBCS and the adjacent region. The mixing between the Subantarctic Shelf Water and the Subtropical Shelf Water, known as the Subtropical Shelf Front (STSF), presented a clear seasonal change in volume. As a consequence of the mixing and of the seasonal oscillation of the STSF position, the stability of the water column inside the SBCS also changes seasonally. Current velocities and associated transports estimated for the Brazil Current (BC) and for the Brazilian Coastal Current (BCC) agree with previous measurements and estimates, stressing the fact that the opposite flow of the BCC occurring during winter in the study region is about 2 orders of magnitude smaller than that of the BC. Seasonal maps of simulated Mean Kinetic Energy and Eddy Kinetic Energy demonstrate the known behavior of the BC and stressed the importance of the mean coastal flow off Argentina throughout the year.

L. F. Mendonça et al. (2017). "Regional modeling of the water masses and circulation annual variability at the Southern Brazilian Continental Shelf". In: *Journal of Geophysical Research: Oceans* 122, pp. 1232–1253. DOI: 10.1002/2016JC011780

Avaliable at: *https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2016JC011780*

The Influence of Sea Ice Dynamics on the Climate Sensitivity and Memory to Increased Antarctic Sea Ice

C. K. Parise, L. P. Pezzi, K. I. Hodges and F. Justino

Abstract

The study analyzes the sensitivity and memory of the Southern Hemisphere coupled climate system to increased Antarctic sea ice (ASI), taking into account the persistence of the sea ice maxima in the current climate. The mechanisms involved in restoring the climate balance under two sets of experiments, which differ in regard to their sea ice models, are discussed. The experiments are perturbed with extremes of ASI and integrated for 10 yr in a large 30-member ensemble. The results show that an ASI maximum is able to persist for 4 yr in the current climate, followed by a negative sea ice phase. The sea ice insulating effect during the positive phase reduces heat fluxes south of 60°S, while at the same time these are intensified at the sea ice edge. The increased air stability over the sea ice field strengthens the polar cell while the baroclinicity increases at midlatitudes. The mean sea level pressure is reduced (increased) over high latitudes (midlatitudes), typical of the southern annular mode (SAM) positive phase. The Southern Ocean (SO) becomes colder and fresher as the sea ice melts mainly through sea ice lateral melting, the consequence of which is an increase in the ocean stability by buoyancy and mixing changes. The climate sensitivity is triggered by the sea ice insulating process and the resulting freshwater pulse (fast response), while the climate equilibrium is restored by the heat stored in the SO subsurface layers (long response). It is concluded that the time needed for the ASI anomaly to be dissipated and/or melted is shortened by the sea ice dynamical processes.

C. K. Parise et al. (2014). "The Influence of Sea Ice Dynamics on the Climate Sensitivity and Memory to Increased Antarctic Sea Ice". In: *Journak of Climate* 28, pp. 9642–9668. DOI: 10.1175/JCLI-D-14-00748.1

Avaliable at: *https://journals.ametsoc.org/doi/10.1175/JCLI-D-14-00748.1*

Modeling the spawning strategies and larval survival of the Brazilian sardine (*Sardinella brasiliensis*)

D. F. Dias, L. P. Pezzi, D. F. M. Gherardi and R. Camargo

Abstract

An Individual Based Model (IBM), coupled with a hydrodynamic model (ROMS), was used to investigate the spawning strategies and larval survival of the Brazilian Sardine in the South Brazil Bight (SBB). ROMS solutions were compared with satellite and field data to assess their representation of the physical environment. Two spawning experiments were performed for the summer along six years, coincident with ichthyoplankton survey cruises. In the first one, eggs were released in spawning habitats inferred from a spatial model. The second experiment simulated a random spawning to test the null hypothesis that there are no preferred spawning sites. Releasing eggs in the predefined spawning habitats increases larval survival, suggesting that the central-southern part of the SBB is more suitable for larvae development because of its thermodynamic characteristics. The Brazilian sardine is also capable of exploring suitable areas for spawning, according to the interannual variability of the SBB. The influence of water temperature, the presence of Cape Frio upwelling, and surface circulation on the spawning process was tested. The Cape Frio upwelling plays an important role in the modulation of Brazilian sardine spawning zones over SBB because of its lower than average water temperature. This has a direct influence on larval survival and on the interannual variability of the Brazilian sardine spawning process. The hydrodynamic condition is crucial in determining the central-southern part of SBB as the most suitable place for spawning because it enhances simulated coastal retention of larvae.

D. F. Dias et al. (2014). "Modeling the spawning strategies and larval survival of the Brazilian sardine (Sardinella brasiliensis)". In: *Progress in Oceanography* 123, pp. 38–53. DOI: 10.1016/j.pocean.2014.03.009

Avaliable at: *http://www.iag.usp.br/pos/meteorologia/biblio/modeling-spawning-strategies-and-larval-survival-brazilian-sardine-sardinella-br*

Sea surface temperature anomalies driven by oceanic local forcing in the Brazil-Malvinas Confluence

I. P. da Silveira and L. P. Pezzi

Abstract

Sea surface temperature (SST) anomaly events in the Brazil-Malvinas Confluence (BMC) were investigated through wavelet analysis and numerical modeling. Wavelet analysis was applied to recognize the main spectral signals of SST anomaly events in the BMC and in the Drake Passage as a first attempt to link middle and high latitudes. The numerical modeling approach was used to clarify the local oceanic dynamics that drive these anomalies. Wavelet analysis pointed to the 8–12-year band as the most energetic band representing remote forcing between high to middle latitudes. Other frequencies observed in the BMC wavelet analysis indicate that part of its variability could also be forced by low-latitude events, such as El Niño. Numerical experiments carried out for the years of 1964 and 1992 (cold and warm El Niño-Southern Oscillation (ENSO) phases) revealed two distinct behaviors that produced negative and positive sea surface temperature anomalies on the BMC region. The first behavior is caused by northward cold flow, Río de la Plata runoff, and upwelling processes. The second behavior is driven by a southward excursion of the Brazil Current (BC) front, alterations in Río de la Plata discharge rates, and most likely by air-sea interactions. Both episodes are characterized by uncoupled behavior between the surface and deeper layers.

I. P. Silveira & L. P. Pezzi (2014). "Sea surface temperature anomalies driven by oceanic local forcing in the Brazil-Malvinas Confluence". In: *Ocean Dynamics* 347.64, pp. 347–360. DOI: 10.1007/s10236-014-0699-4

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