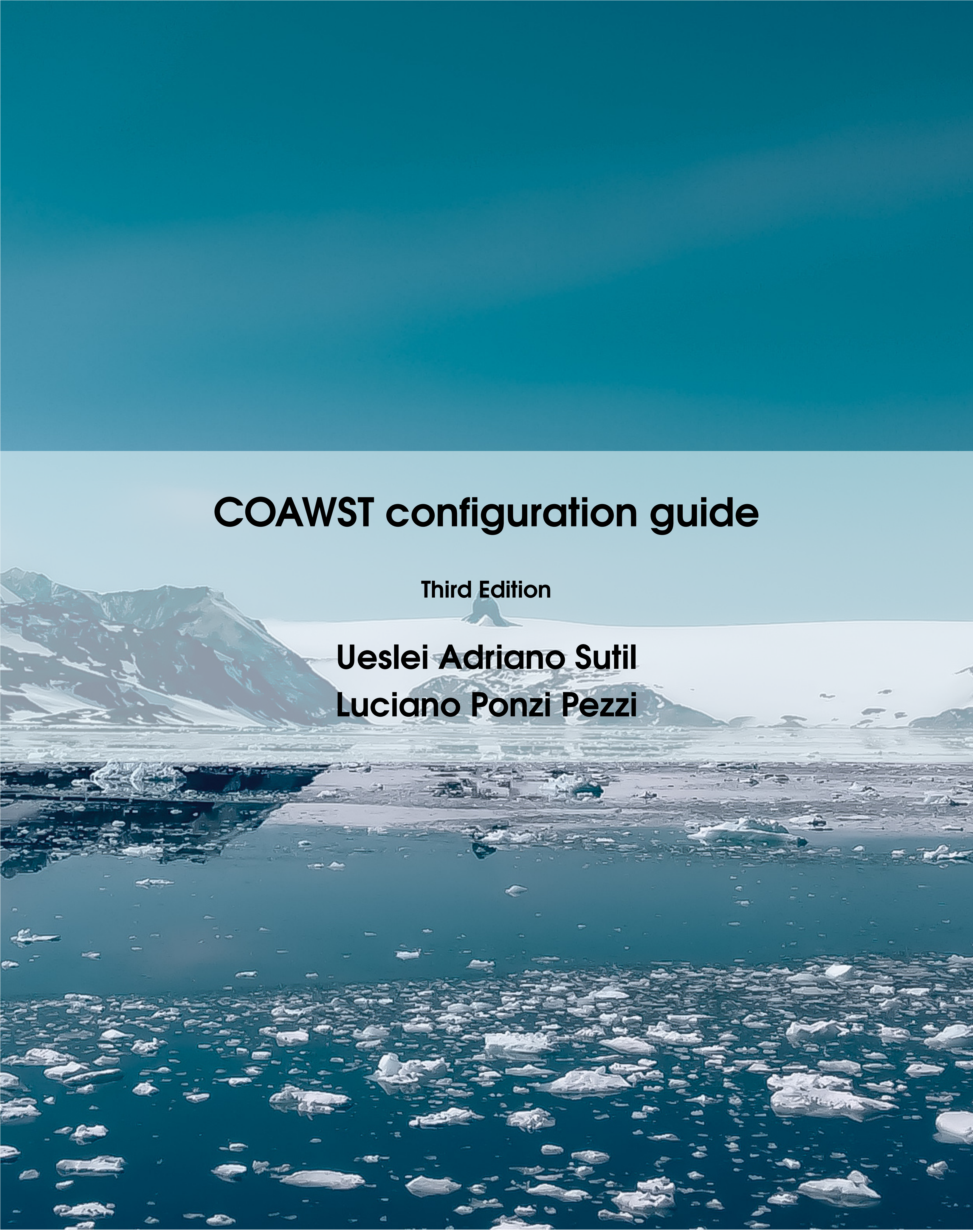

COAWST configuration guide

Third Edition

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Third edition
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Reviewers

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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.

To cite the **third edition**, use the following:

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SUTIL, U. A.; PEZZI, L. P. Guia prático para utilização do COAWST. São José dos Campos: INPE, 2018. 86 p. IBI: <8JMKD3MGP3W34R/3RQSQ2L>. ISBN: <978-85-17-00093-5>. Avaliable at: <http://urlib.net/rep/8JMKD3MGP3W34R/3RQSQ2L>.

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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 **??**;
- ***real***: Executable program to generate the initial condition and the boundary forces of the WRF. More information in the Section **??**;
- ***WPS***: Package with three programs to generate the files to be used in *real*. More information in the Section **??**;
- ***geogrid***: Program to, mainly, generate the WRF grid domain. More information in the section **??**;
- ***ungrib***: Briefly, the program that extracts the data in *GRIB* format. More information in the Section **??**;
- ***metgrid***: Briefly, the program that interpolates the data generated by *ungrib*. More information in the Section **??**;
- **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.

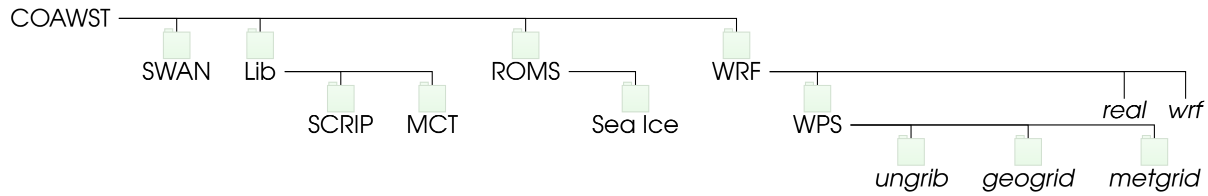


Figure 1.1. COAWST folder structure

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.

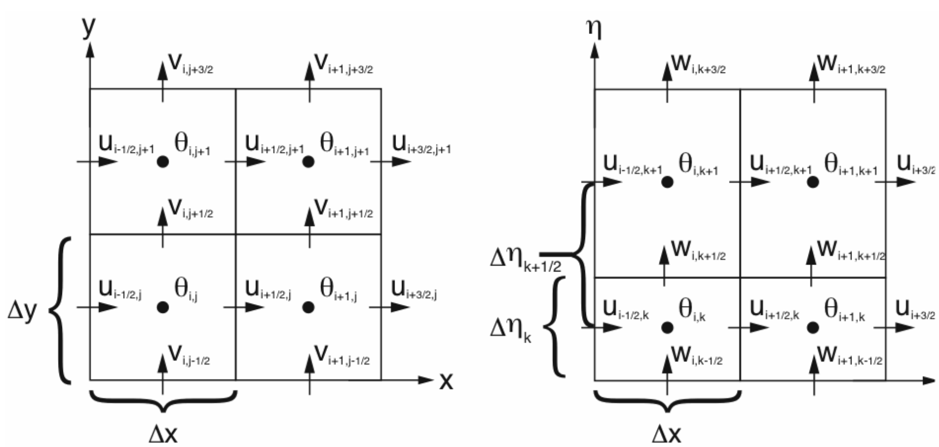


Figure 1.2. Horizontal and vertical grid of Weather Research and Forecast (WRF) using the Arawaka-C grid. The horizontal and vertical components of velocity (**u**, **v** and **w**) are positioned along the faces of the grids and the thermodynamic variables (θ) are positioned in the center of each grid.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

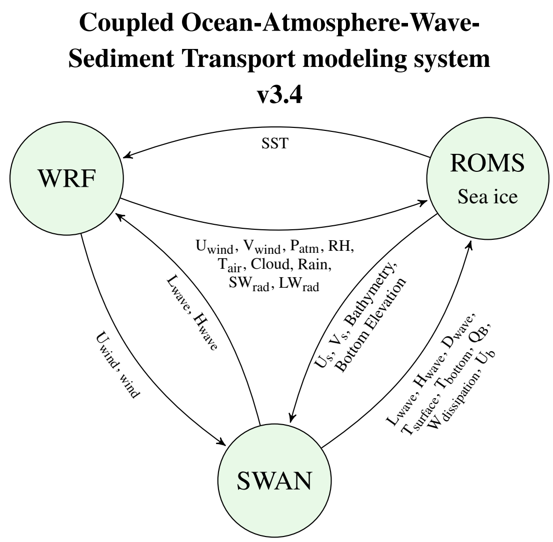


Figure 1.3. Diagram about the exchange of information between the main models that make up the COAWST modeling system. (Warner et al., 2008)

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:

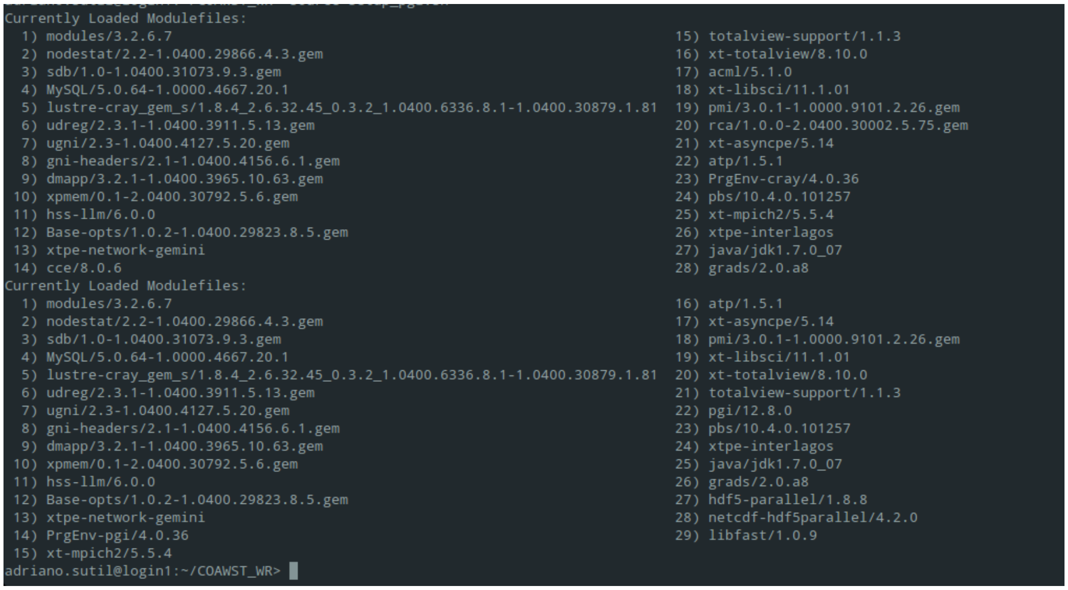

```
Currently Loaded Modulefiles:
  1) modules/3.2.6.7                                                          15) totalview-support/1.1.3
  2) nodestat/2.2-1.0400.29866.4.3.gem                                        16) xt-totalview/8.10.0
  3) sdb/1.0-1.0400.31073.9.3.gem                                             17) acml/5.1.0
  4) MySQL/5.0.64-1.0000.4667.20.1                                            18) xt-libsci/11.1.01
  5) lustre-cray_gem_s/1.8.4_2.6.32.45_0.3.2_1.0400.6336.8.1-1.0400.30879.1.81  19) pmi/3.0.1-1.0000.9101.2.26.gem
  6) udreg/2.3.1-1.0400.3911.5.13.gem                                         20) rca/1.0.0-2.0400.30002.5.75.gem
  7) ugni/2.3-1.0400.4127.5.20.gem                                            21) xt-asyncpe/5.14
  8) gni-headers/2.1-1.0400.4156.6.1.gem                                      22) atp/1.5.1
  9) dmapp/3.2.1-1.0400.3965.10.63.gem                                        23) PrgEnv-cray/4.0.36
 10) xpmem/0.1-2.0400.30792.5.6.gem                                           24) pbs/10.4.0.101257
 11) hss-llm/6.0.0                                                            25) xt-mpich2/5.5.4
 12) Base-opts/1.0.2-1.0400.29823.8.5.gem                                     26) xtpe-interlagos
 13) xtpe-network-gemini                                                      27) java/jdk1.7.0_07
 14) cce/8.0.6                                                                28) grads/2.0.a8
Currently Loaded Modulefiles:
  1) modules/3.2.6.7                                                          16) atp/1.5.1
  2) nodestat/2.2-1.0400.29866.4.3.gem                                        17) xt-asyncpe/5.14
  3) sdb/1.0-1.0400.31073.9.3.gem                                             18) pmi/3.0.1-1.0000.9101.2.26.gem
  4) MySQL/5.0.64-1.0000.4667.20.1                                            19) xt-libsci/11.1.01
  5) lustre-cray_gem_s/1.8.4_2.6.32.45_0.3.2_1.0400.6336.8.1-1.0400.30879.1.81  20) xt-totalview/8.10.0
  6) udreg/2.3.1-1.0400.3911.5.13.gem                                         21) totalview-support/1.1.3
  7) ugni/2.3-1.0400.4127.5.20.gem                                            22) pgi/12.8.0
  8) gni-headers/2.1-1.0400.4156.6.1.gem                                      23) pbs/10.4.0.101257
  9) dmapp/3.2.1-1.0400.3965.10.63.gem                                        24) xtpe-interlagos
 10) xpmem/0.1-2.0400.30792.5.6.gem                                           25) java/jdk1.7.0_07
 11) hss-llm/6.0.0                                                            26) grads/2.0.a8
 12) Base-opts/1.0.2-1.0400.29823.8.5.gem                                     27) hdf5-parallel/1.8.8
 13) xtpe-network-gemini                                                      28) netcdf-hdf5parallel/4.2.0
 14) PrgEnv-pgi/4.0.36                                                        29) libfast/1.0.9
 15) xt-mpich2/5.5.4
adriano.sutil@login1:~/COAWST_WR>
```

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

Enter the MCT folder directory:

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

Open the file *Makefile.conf*:

```
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:

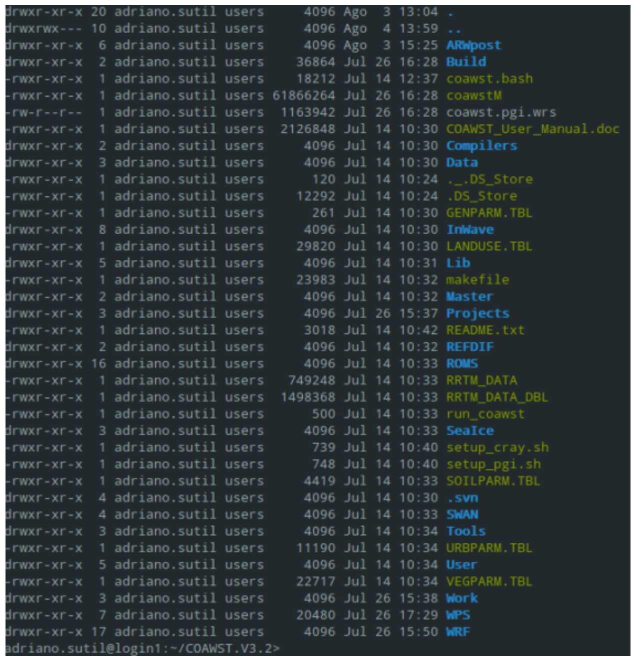
```
make
make install
```

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

2.9 CCompiling 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.



```
drwxr-xr-x 20 adriano.sutil users     4096 Ago  3 13:04 .
drwxrwx--- 10 adriano.sutil users     4096 Ago  4 13:59 ..
drwxr-xr-x  6 adriano.sutil users     4096 Ago  3 15:25 ARWpost
drwxr-xr-x  2 adriano.sutil users    36864 Jul 26 16:28 Build
-rwxr-xr-x  1 adriano.sutil users    18212 Jul 14 12:37 coawst.bash
-rwxr-xr-x  1 adriano.sutil users 61866264 Jul 26 16:28 coawstM
-rw-r--r--  1 adriano.sutil users  1163942 Jul 26 16:28 coawst.pgi.wrs
-rwxr-xr-x  1 adriano.sutil users  2126848 Jul 14 10:30 COAWST_User_Manual.doc
drwxr-xr-x  2 adriano.sutil users     4096 Jul 14 10:30 Compilers
drwxr-xr-x  3 adriano.sutil users     4096 Jul 14 10:30 Data
-rwxr-xr-x  1 adriano.sutil users      120 Jul 14 10:24 ._.DS_Store
-rwxr-xr-x  1 adriano.sutil users    12292 Jul 14 10:24 .DS_Store
-rwxr-xr-x  1 adriano.sutil users      261 Jul 14 10:30 GENPARM.TBL
drwxr-xr-x  8 adriano.sutil users     4096 Jul 14 10:30 InWave
-rwxr-xr-x  1 adriano.sutil users    29820 Jul 14 10:30 LANDUSE.TBL
drwxr-xr-x  5 adriano.sutil users     4096 Jul 14 10:31 Lib
-rwxr-xr-x  1 adriano.sutil users    23983 Jul 14 10:32 makefile
drwxr-xr-x  2 adriano.sutil users     4096 Jul 14 10:32 Master
drwxr-xr-x  3 adriano.sutil users     4096 Jul 26 15:37 Projects
-rwxr-xr-x  1 adriano.sutil users     3018 Jul 14 10:42 README.txt
drwxr-xr-x  2 adriano.sutil users     4096 Jul 14 10:32 REFDIF
drwxr-xr-x 16 adriano.sutil users     4096 Jul 14 10:33 ROMS
-rwxr-xr-x  1 adriano.sutil users   749248 Jul 14 10:33 RRTM_DATA
-rwxr-xr-x  1 adriano.sutil users  1498368 Jul 14 10:33 RRTM_DATA_DBL
-rwxr-xr-x  1 adriano.sutil users      500 Jul 14 10:33 run_coawst
drwxr-xr-x  3 adriano.sutil users     4096 Jul 14 10:33 SeaIce
-rwxr-xr-x  1 adriano.sutil users      739 Jul 14 10:40 setup_cray.sh
-rwxr-xr-x  1 adriano.sutil users      748 Jul 14 10:40 setup_pgi.sh
-rwxr-xr-x  1 adriano.sutil users     4419 Jul 14 10:33 SOILPARM.TBL
drwxr-xr-x  4 adriano.sutil users     4096 Jul 14 10:30 .svn
drwxr-xr-x  4 adriano.sutil users     4096 Jul 14 10:33 SWAN
drwxr-xr-x  3 adriano.sutil users     4096 Jul 14 10:34 Tools
-rwxr-xr-x  1 adriano.sutil users    11190 Jul 14 10:34 URBPARM.TBL
drwxr-xr-x  5 adriano.sutil users     4096 Jul 14 10:34 User
-rwxr-xr-x  1 adriano.sutil users    22717 Jul 14 10:34 VEGPARM.TBL
drwxr-xr-x  3 adriano.sutil users     4096 Jul 26 15:38 Work
drwxr-xr-x  7 adriano.sutil users    20480 Jul 26 17:29 WPS
drwxr-xr-x 17 adriano.sutil users     4096 Jul 26 15:50 WRF
adriano.sutil@login1:~/COAWST.V3.2>
```

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:

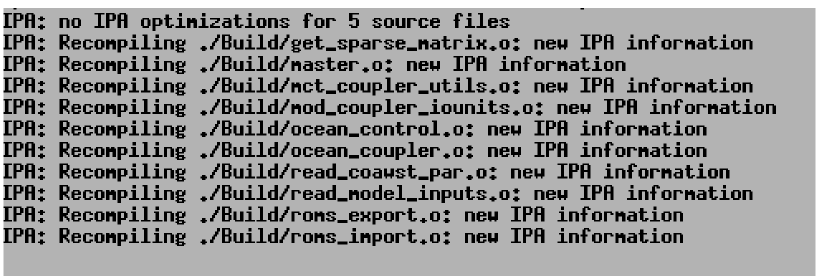
```
export   COAWST_APPLICATION=Sandy
export   MY_ROOT_DIR=${HOME}/COAWST
export   MY_HEADER_DIR=${MY_PROJECT_DIR}/Projects/Sandy
```

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
```



```
IPA: no IPA optimizations for 5 source files
IPA: Recompiling ./Build/get_sparse_matrix.o: new IPA information
IPA: Recompiling ./Build/master.o: new IPA information
IPA: Recompiling ./Build/mct_coupler_utils.o: new IPA information
IPA: Recompiling ./Build/mod_coupler_iounits.o: new IPA information
IPA: Recompiling ./Build/ocean_control.o: new IPA information
IPA: Recompiling ./Build/ocean_coupler.o: new IPA information
IPA: Recompiling ./Build/read_coawst_par.o: new IPA information
IPA: Recompiling ./Build/read_model_inputs.o: new IPA information
IPA: Recompiling ./Build/roms_export.o: new IPA information
IPA: Recompiling ./Build/roms_import.o: new IPA information
```

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. Características do COAWST

Até aqui aprendemos como utilizar o cluster Kerana e como compilar e rodar um simples caso teste do COAWST. A partir de agora entraremos nas especificidades dos modelos, como por exemplo, alterar o número de processadores utilizados e a taxa de troca de informações entre eles.

3.1 Arquivos estruturais dos modelos

Como você pode ter notado ao simular o caso Sandy, os modelos possuem arquivos gerenciais que auxiliam o usuário na definição do projeto:

O ROMS utiliza o arquivo *sandy.h* como arquivo que contém as opções de pré-processamento de C que definem o projeto. Acesse o site *https://www.myroms.org/wiki/cppdefs.h* para conhecer as definições disponíveis para o arquivo. O ROMS também utiliza o *ocean_sandy.in* como entrada padrão para executar o modelo. Este arquivo define as dimensões espaciais do projeto e parâmetros que não são informados durante a compilação, como por exemplo os passo de tempo, coeficientes e constantes físicas, configuração de coordenadas verticais, sinalizadores para controlar a frequência de saída, entre outros fatores. É possível aprender mais sobre este arquivo acessando o site *https://www.myroms.org/wiki/ocean.in*.

O WRF utiliza o arquivo *namelist.input* para gerenciar as informações sobre o projeto, bem como os esquemas de parametrização físicas que serão utilizados. Para aprender sobre a descrição do arquivo, visite *https://esrl.noaa.gov/gsd/wrfportal/namelist_input_options.html*. Para aprender sobre as opções físicas do modelo e as referências de cada um deles, acesse *http://www2.mmm.ucar.edu/wrf/users/phys_references.html*.

O SWAN utiliza o arquivo *swan_sandy.in* como gerenciador. Nele estão descritos diversos parâmetros, c omo a descrição do projeto, os dados de entrada, da grade e das condições de contorno e iniciais, as parametrizações físicas de ondas, entre outros. Para saber mais sobre como configurar o arquivo, visite a guia *User Manual* no site *http://swanmodel.sourceforge.net/* e procure pela seção *Description of commands*.

3.2 Modificando o número de processadores

3.2.1 No ROMS

No ROMS, os processadores estão localizados no arquivo *ocean.in*, que fica dentro da pasta *Projects*, e se chamam *NtileI* e *NtileJ*. Um exemplo está na Figura 3.1. Neste caso o ROMS reservará 320 processadores para ser executado, pois 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. Representação do número de processadores usados no ROMS.

3.2.2 No WRF

Para alterar o número de processadores do WRF é necessário modificar o arquivo *namelist.input*. Nele existem as variáveis *nproc_x* e *nproc_y*, como na Figura 3.2. Neste caso serão reservados 320 processadores para o modelo atmosférico.

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

Figure 3.2. Representação do número de processadores para o WRF.

3.2.3 No SWAN

O arquivo *.in* do SWAN não discrimina os números de processadores usados, portanto basta alterar o número de processadores dele no *coupling.in*, como será mostrado na subseção a seguir.

3.2.4 No COAWST

Agora que foram modificados, individualmente, o número de processadores que serão utilisados pelos modelos, o acoplador precisa ser informado sobre esta quantidade de processadores. Essa informação é passada no arquivo *coupling.in*. Dentro dele deverá constar o número total de processadores a serem utilizados pelos modelos ROMS, WRF e SWAN, como na Figura 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. Representação do número de processadores para cada módulo do COAWST.

O *NnodesATM* é referente ao total de processadores utilizados pelo WRF, o *NnodesWAV* é o total do SWAN e o *NnodesOCN* o do ROMS. Basta mudar de acordo com o total de processadores utilizados nos passos anteriores.

Por fim, é preciso modificar o total de processadores no *run.sh*, usado para submeter o experimento. Some o total de processadores usados pelos três modelos, seguindo a Equação 3.1:

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

Onde o *TotalProc* é soma de todos os processadores usados nos modelos.

Agora abra o arquivo *run.sh*, localizado dentro da pasta *Work*, e procure pela linha a seguir:

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

E pela linha:

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

Modifique o número *3* pelo número total de processadores utilizados.

3.3 Modificando o intervalo de tempo do acoplamento entre os modelos

Para modificar o intervalo de troca de informações entre os modelos, abra o arquivo *coupling.in* e modifique as variáveis *TI_ATM2WAV*, *TI_ATM2OCN*, *TI_WAV2ATM*, *TI_WAV2OCN*, *TI_OCN2WAV*, *TI_OCN2ATM*, como na Figura 3.4.

ATENÇÃO A unidade da taxa de troca de informações é definida em segundos.

```
! 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. Intervalo de troca de informações entre os modelos utilizados no COAWST. Neste exemplo, a troca ocorrerá a cada 900 segundos.

4. 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`

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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

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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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