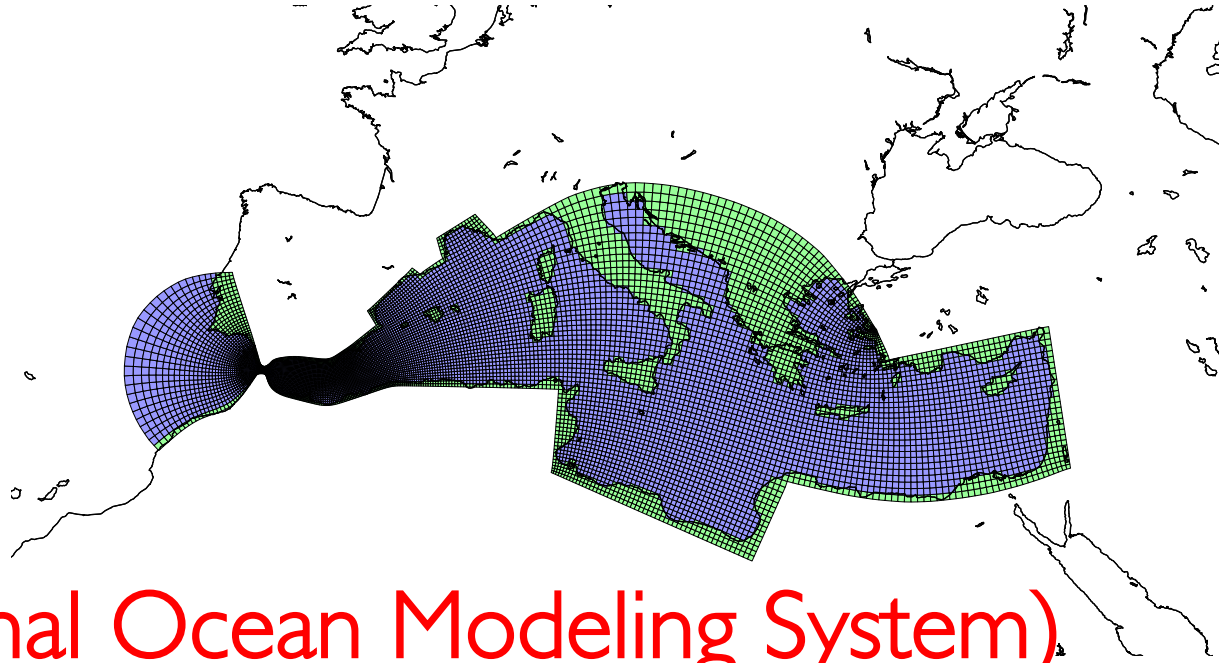


ROMS (Regional Ocean Modeling System) Tutorial

Enrique Curchitser[1] & Ufuk Turuncoglu[2,3]

[1] Rutgers University, Department of Environmental Sciences, US
[2] Istanbul Technical University, Informatics Institute, Turkey
[3] ICTP, Earth System Physics Section, Italy

28 Sept. – 1 Oct. 2015: School on Ocean Climate Modelling: Physical and Biogeochemical Dynamics of Semi- Enclosed Seas (smr2711)

Outline

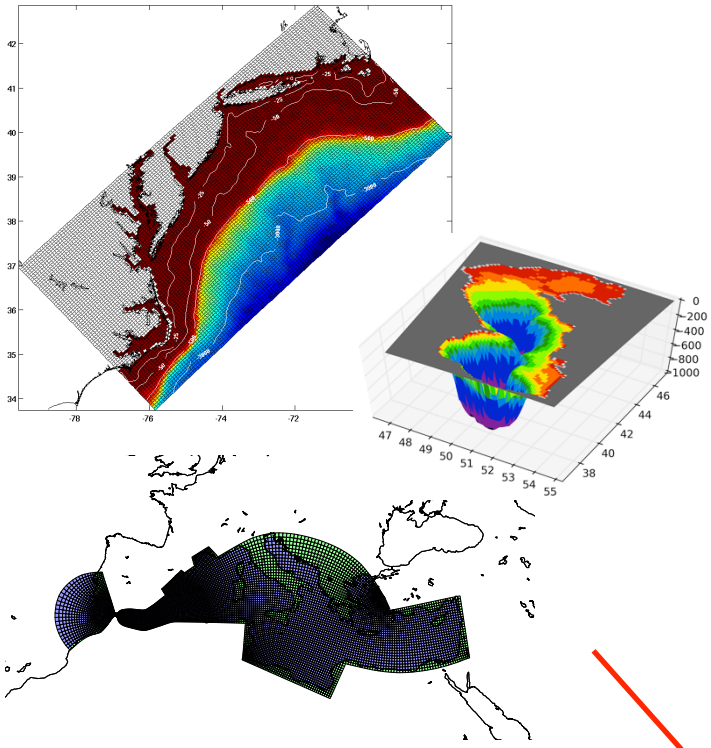
- Introduction to ROMS
  - Requirements
  - Key issues about grid generation
  - Initial and boundary conditions
- Installation
- Test case (UPWELLING)

Regional Ocean Modeling System (ROMS)

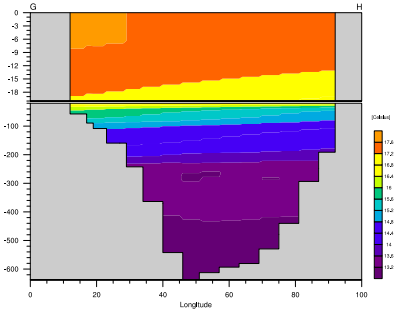
- It is a three-dimensional, free-surface, terrain-following (via s-coordinates) numerical model.
- Assumptions:
  - Boussinesq (density is nearly constant)
    - It simplifies equation of motion
    - water is incompressible
    - velocities in the ocean is small compared with speed of sound
    - vertical scale of motion is also small
  - Hydrostatic (neglect of inertial accelerations in the vertical momentum eq.)
    - It simplifies vertical component of the velocity
    - Strict hydrostatic balance in all scales
- Wide range of applications
- More info: http://www.people.arsc.edu/~kate/ROMS/manual_2012.pdf

Requirements

Grid Generation

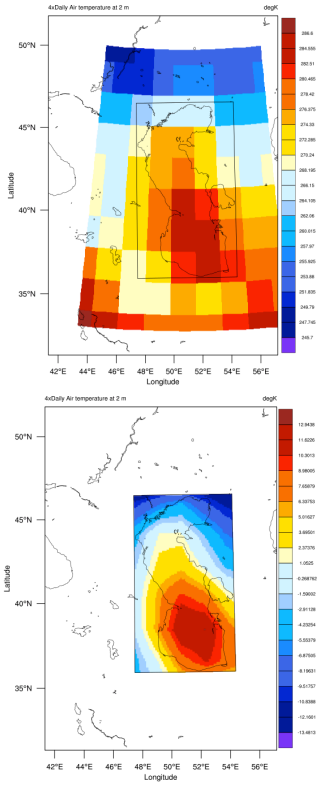


Initial and Boundary Condition



T, S, U, V, ZETA

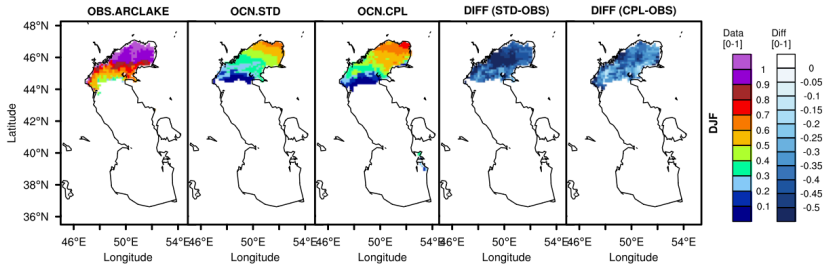
Atmospheric Forcing

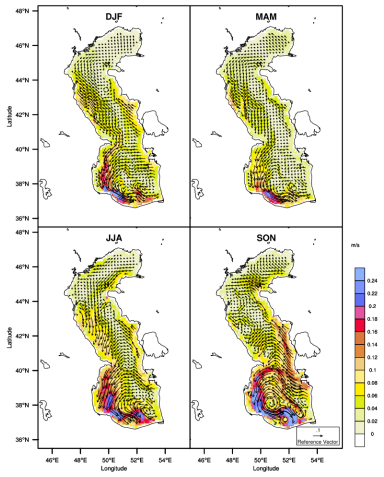


Heat + Momentum Fluxes or Atm. Cond.

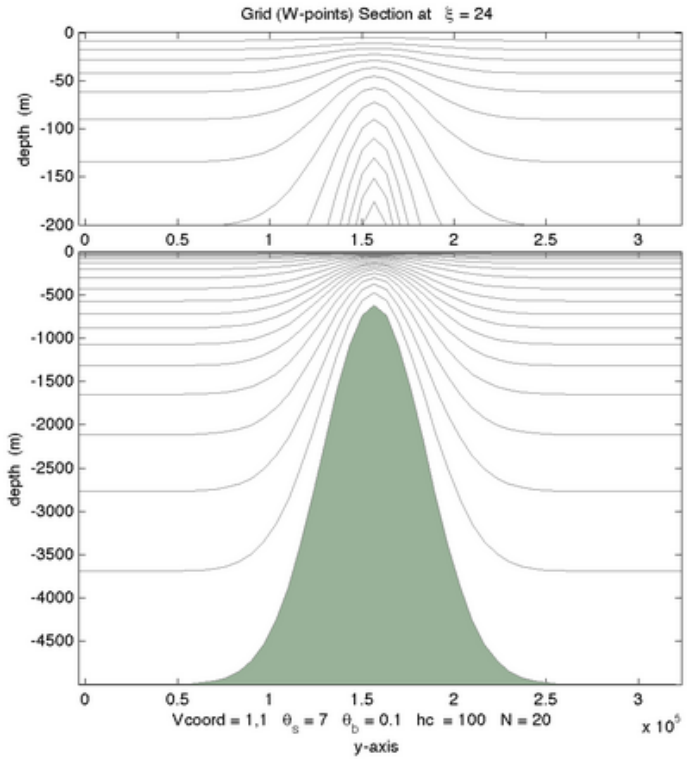
Model input parameters

Simulation





Grid Generation



- Realistic and/or analytic
- ROMS uses s-coordinate in vertical and it follows bathymetry
- The distribution of vertical layers can be controlled using set of parameters
- In horizontal, curvilinear grid is supported
- Grid Generation Tools:
  - MATLAB: SeaGrid, Gridgen, EasyGrid …
  - Python: octant, pyroms, …
  - Analytic grid can be also defined using Fortran
- The grid generation plays crucial role in the stability

Grid Generation

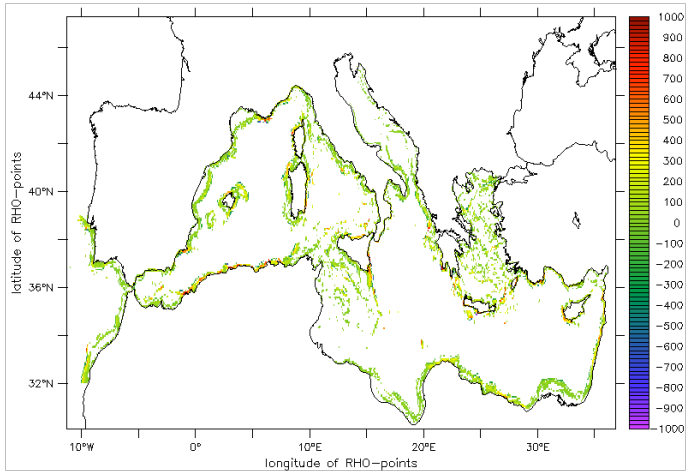
- Bathymetry smoothing:

```
GET_2DFLD   - surface air relative humidity,              t =     0 00:00:00
              (Rec=0001, Index=1, File: CAS_forcing_Qair_1996-2008.nc)
              (Tmin=          0.0000 Tmax=       4748.8750)
              (Min =  2.00517376E-03 Max =  7.59032093E-03)
GET_2DFLD   - rain fall rate,                             t =     0 00:00:00
              (Rec=0001, Index=1, File: CAS_forcing_rain_1996-2008.nc)
              (Tmin=          0.0000 Tmax=       4748.8750)
              (Min =  0.00000000E+00 Max =  1.07682618E-05)

Maximum grid stiffness ratios:  rx0 =   2.500000E-01 (Beckmann and Haidvogel)
                                rx1 =   3.998703E+00 (Haney)

Initial basin volumes: TotVolume =  7.2973633985E+13 m3
                       MinVolume =  7.9395051795E+06 m3
                       MaxVolume =  1.8480204838E+10 m3
                         Max/Min =  2.3276267753E+03
```

H_{smooth}-H_{raw}



- Grid stiffness ratios:

$$r_{xo} = \max\left(\frac{\Delta h}{2\bar{h}}\right) = \max\left(\frac{|h_i - h_{i-1}|}{h_i + h_{i-1})}\right)$$

Beckman & Haidvogel Number (1993)
Reduced by smoothing < 0.25

$$r_{x1} = \max\left(\frac{z_{i,j,k} - z_{i-1,j,k} + z_{i,j,k-1} - z_{i-1,j,k-1}}{z_{i,j,k} + z_{i-1,j,k} - z_{i,j,k-1} - z_{i-1,j,k-1}}\right)$$

Haney Number (1991)
Reduced by smoothing and vert. coordinate modification < 6.0

- Tool: Matlab smoothing toolbox (LP_Bathymetry)

http://drobilica.irb.hr/~mathieu/Bathymetry/

Initial and Lateral Boundary Conditions

- Realistic and/or analytic
- Requires (3d for IC and 2d for Lateral BC)
  - salinity,
  - temperature
  - current (u and v)
  - sea surface height fields.
- The input files are defined in netCDF format
- The input files should be recreated when the horizontal and vertical grid changed!
  - There is no need to change files for atmospheric forcing if horizontal grid is same
- Atmospheric forcing
  - Momentum, heat and freshwater fluxes or atmospheric conditions

Installation

- The code is distributed using SVN repository
- Users need to register to access the code
  https://www.myroms.org/index.php?page=RomsCode
- Get code
  svn checkout https://www.myroms.org/svn/src/trunk MyDir
- Directories

```
.
|-- Atmosphere
|-- Compilers                OS/Architecture/compiler specific files
|-- Data
|-- Lib
|-- Master
|-- ROMS                     ROMS source code, files related with test cases
|-- User
|-- Waves
`-- makefile
```

Installation

- Directories under ROMS/

```
.
|-- Adjoint
|-- Bin                                   ROMS build script, build.sh
|-- Drivers
|-- External                              Input parameter files for tests, *.in and varinfo.dat
|-- Functionals                           Files to create analytic initial and boundary conditions
|-- Include                               Option files for test cases, CPP options
|-- License_ROMS.txt
|-- Modules
|-- Nonlinear                             Source files for non-linear model
|-- Obsolete
|-- Programs
|-- Representer
|-- SeaIce
|-- Tangent
|-- Utility                               Source files for utility modules
`-- Version
```

Installation

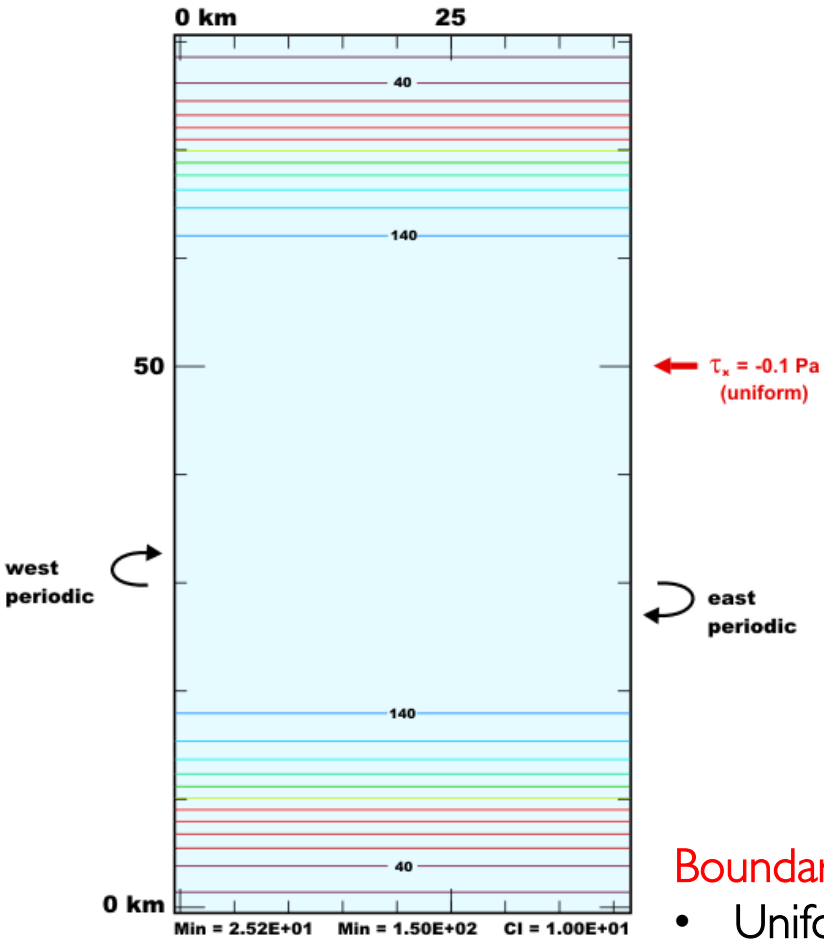
- Main steps:
  - Modify build environment (i.e. Compilers/Linux-ifort.mk)
    - External libraries (netCDF, HDF etc.)
    - MPI compiler (OpenMPI, IntelMPI, …)
    - OpenMP ?
  - Copy build script from ROMS/Bin/build.sh to installation directory
  - Create or copy application specific header file
    - CPP options for model customization
  - Edit build.sh
    - Case identifier (i.e. UPWELLING)
    - Specify source directory
    - MPI, compiler definitions
  - Run build script to install model, ./build.sh

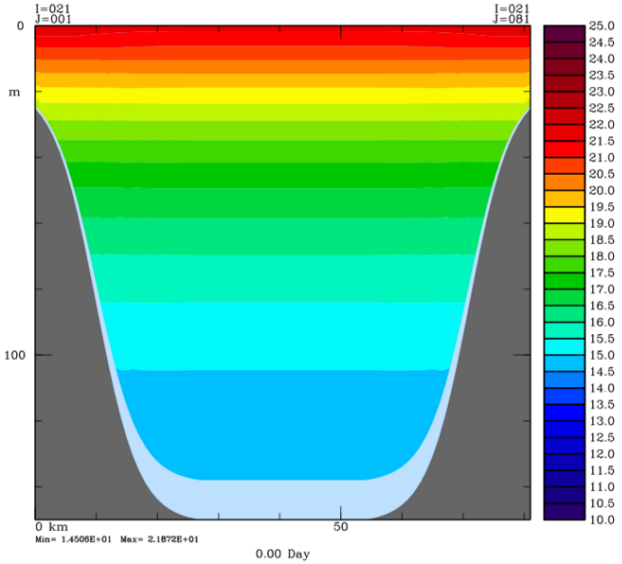
Installation

- Application specific options are defined by CPP definitions
- CPP definitions act as a filter to create customized model source code
- CPP options include:
  - Momentum equations (mixing, advection, bottom friction, …)
  - Tracer equations (mixing, advection, relaxation, rivers …)
  - Pressure gradient algorithm
  - Atmospheric boundary conditions (i.e. bulk flux alg.)
  - Analytical field definitions (grid, initial conditions etc.)
  - Vertical mixing parameterizations (GLS, MY, LMD, …)
  - Open boundary conditions
  - Biological (i.e. NPZD, EcoSim) + Sediment Transport models
  - Sea-ice …

Test case

- Wind-Driven Upwelling/Downwelling over a Periodic Channel





Initial Condition

- Temperature stratification
- No motion (u, v and w = 0)

Boundary Condition

- Uniform wind blowing from east to west at 0.1 Pa

S-coordinate to depth

- ROMS_TOOLS is an alternative to MATLAB toolbox
- It is written in NCL
- Usage
  - Get script

    git clone https://github.com/uturuncoglu/ROMS_TOOLS.git
  - Edit ROMS_convert_s2z.ncl and specify desired depth levels and list of variables
  - Run script using ncl ROMS_convert_s2z.ncl command
  - Warnings written at the beginning can be ignored. It is about defining dimensions that are already defined in the result file

Questions!

Contact:

Personal web: http://faculty.itu.edu.tr/turuncogl1/

E-mail: u.utku.turuncoglu@be.itu.edu.tr