Forcing a realistic ocean simulation model

Reanalysis

https://reanalyses.org/ocean/overview-current-reanalyses

DRAKKAR ocean forcing

http://www.drakkar-ocean.eu/forcing-the-ocean

Heat Budget Slides

http://www.geo.cornell.edu/ocean/p_ocean/ppt_notes/4_HeatFlux.pdf

Major Heat Budget Terms at the Sea Surface

$$Q_{NET} = Q_{SW} + Q_{LW} + Q_{S} + Q_{L} + Q_{adV}$$

Surface Heat Flux Across Air-Sea Interface

1. Shortwave Radiation Heat Flux Q_{SW}
2. Longwave Radiation Heat Flux Q_{LW}
3. Latent Heat Flux Q_{L}
4. Sensible Heat Flux Q_{S}

Advective Heat Flux By Ocean Currents Q_{adV}

Shortwave Radiation Heat Flux (Q_{SW})
Annual Average = +30 to +260 Wm^{-2}

<u>Major Terms</u>

Solar Inclination - Path length through atmosphere

Clouds

Day Length

<u>Minor Terms</u>

Cross-sectional Area Projected Normal to Incoming Radiation

Reflectivity of the Ocean Surface
(sun angle, wavelength and sea-state)

Aerosols and Absorbing Gases (e.g., O_2, CO_2, H_2O)

Longwave Radiation Heat Flux (Q_{LW})
Annual Average = -60 to -30 Wm^{-2}

<u>Major Terms</u>

1. **Absorption by Clouds**
   a) **Cloud Thickness**
   b) **Cloud Height**
2. **Absorption by Water Vapor Content**

<u>Minor Terms</u>

1. **Ocean Temperature** (Blackbody Radiation)
   a) for ocean at 290K Radiation Peaks at about 10μm
   b) Warmer water radiates more heat
2. **Sea Ice**

Latent Heat Flux (Q_L)
Annual Average -130 to -10 Wm^{-2}

Major Terms

1. Wind Speed
2. Relative Humidity

Sensible Heat Flux (Q_S)
Annual Average -42 to -2 Wm^{-2}

Major Terms

1. Difference Between Air and Sea Temperature
2. Wind Speed

High Wind and Large Temperature Differences Cause Large Heat Fluxes (Think of it as the "Wind-Chill Factor" for the Oceans)

Bulk Formula for Sensible and Latent Heat Fluxes

$$Q_S = \rho C_P C_S U_{10}(t_s - t_a)$$

$$Q_L = \rho L_E C_L U_{10}(q_s - q_a)$$

C_P = Specific Heat Capacity of Air

C_S = Sensible Heat Transfer Coefficient

C_L = Latent Heat Transfer Coefficient

L_E = Latent Heat of Evaporation

U_{10} = Wind Speed at 10m above sea surface

t_s/t_a = sea and air temperature

q_s/q_a = specific humidity at sea-surface and 10m above

Horizontal Boundary Conditions

Gradient boundary condition

This boundary condition is extremely simple and consists of setting the gradient of a field to zero at the edge. The outside value is set equal to the closest interior value.

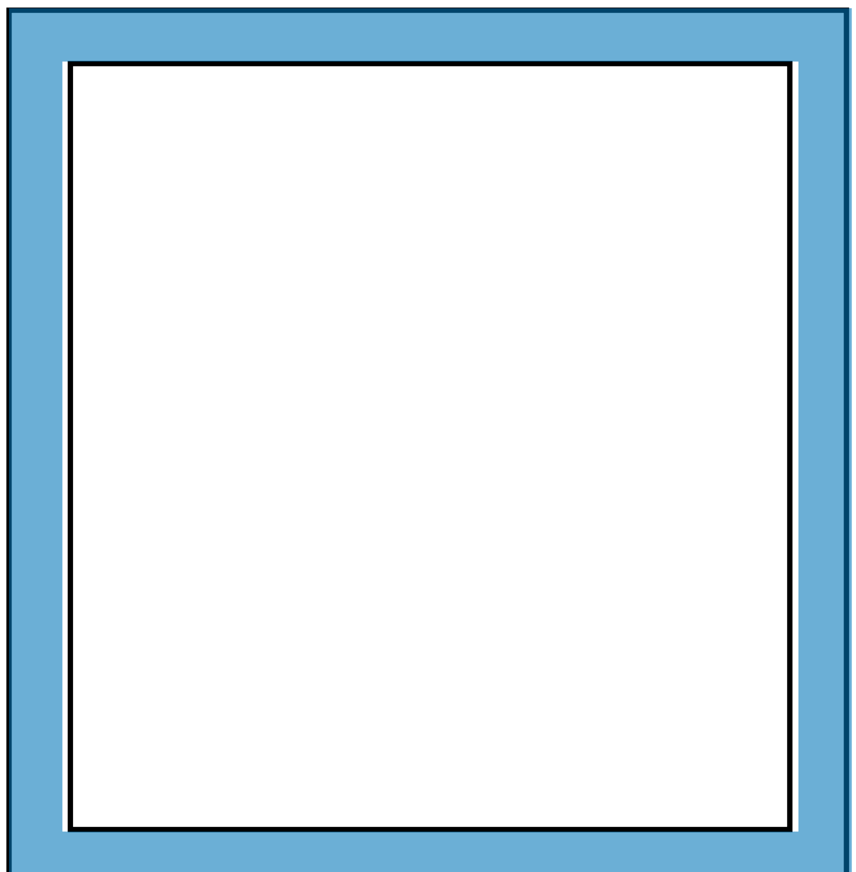
Wall boundary condition

ROMS now assumes a wall condition if no other boundary condition is chosen. This is a zero gradient condition for tracers and the surface elevation and zero flow for the normal velocity. For tangential velocities, the wall is treated as either no-slip or free-slip, depending on the value of gamma2 chosen by the user.

Horizontal Open Boundary Conditions (OBC)

Horizontal Boundary Conditions

ROMS comes with a variety of boundary conditions, including open, closed, and periodic. See Marchesiello *et al.* (2001) for a more thorough exploration of the options. Some options require a value for the boundary points from either an included analytic expression (Functionals) or from an external NetCDF file. Here, ϕ^{ext} represents the exterior value of a quantity ϕ.



Horizontal Open Boundary Conditions (OBC)

Clamped boundary condition

Almost as simple is setting the boundary value to a known exterior value.

$$\phi = \phi^{\text{ext}} \tag{1}$$

momentum

Flather boundary condition

For the normal component of the barotropic velocity, one option is to radiate out deviations from exterior values at the speed of the external gravity waves (Flather (1976)):

$$\overline{u} = \overline{u}^{\text{ext}} - \sqrt{\frac{g}{D}}\left(\zeta - \zeta^{\text{ext}}\right) \tag{2}$$

The exterior values are often used to provide tidal boundary contitions to the barotropic mode. However, there are times when only the tidal elevation is known. A reduced physics option is available for estimating $\overline{u}^{\text{ext}}$ in that case.

Horizontal Open Boundary Conditions (OBC)

Chapman boundary condition

Sea level elevation

The corresponding condition for surface elevation was investigated by Chapman (1985), assuming all outgoing signals leave at the shallow-water wave speed of $\sqrt{gD}$. This can be useful when using the Flather condition on the 2-D momentum equations.

$$\frac{\partial \zeta}{\partial t} = \pm \sqrt{gD} \frac{\partial \zeta}{\partial \xi} \qquad (3)$$

The time derivative here can be handled either explicitly or implicitly. The model uses an implicit timestep, with the term $\frac{\partial \zeta}{\partial \xi}$ being evaluated at the new timestep.

Horizontal Open Boundary Conditions (OBC)

Radiation boundary condition

3D variables

In realistic domains, open boundary conditions can be extremely difficult to get right. There are situations in which incoming flow and outgoing flow happen along the same boundary or even at different depths at the same horizontal location. Orlanski (1976) proposed a radiation scheme in which a local normal phase velocity is computed and used to radiate things out (if it is indeed going out). This works well for a wave propagating normal to the boundary, but has problems when waves approach the boundary at an angle. Raymond and Kuo (1984) have modified the scheme to account for propagation in all three directions. In ROMS, only the two horizontal directions are accounted for (with the recommended RADIATION_2D option):

$$\frac{\partial \phi}{\partial t} = -\left(\phi_\xi \frac{\partial \phi}{\partial \xi} + \phi_\eta \frac{\partial \phi}{\partial \eta})\right) \qquad (4)$$

Solve Wave Equation @OBC

where

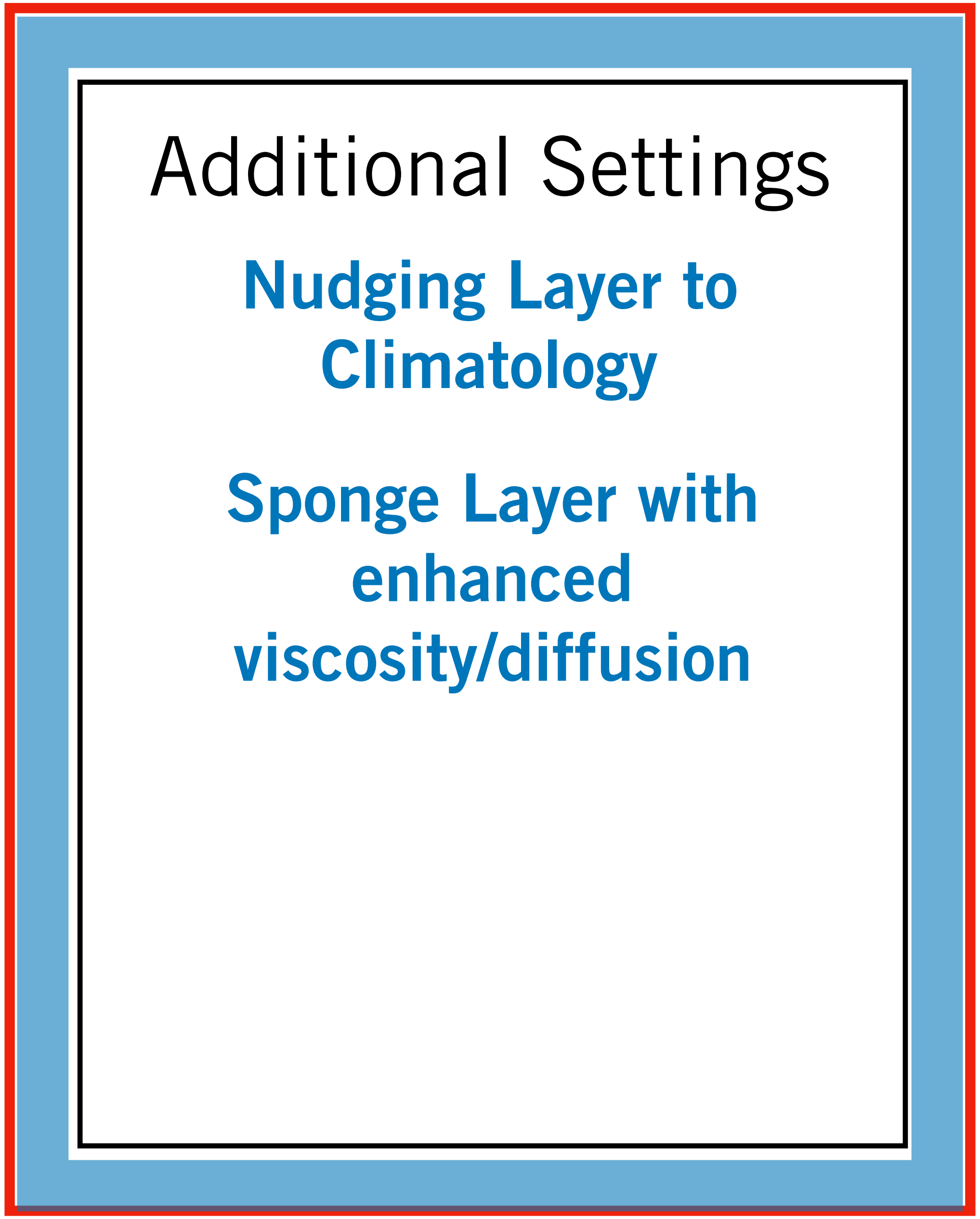
$$\phi_\xi = \frac{F \frac{\partial \phi}{\partial \xi}}{\left(\frac{\partial \phi}{\partial \xi}\right)^2 + \left(\frac{\partial \phi}{\partial \eta}\right)^2}$$

$$\phi_\eta = \frac{F \frac{\partial \phi}{\partial \eta}}{\left(\frac{\partial \phi}{\partial \xi}\right)^2 + \left(\frac{\partial \phi}{\partial \eta}\right)^2} \qquad (5)$$

$$F = -\frac{\partial \phi}{\partial t}$$

Velocity of propagation at OBC

Horizontal Open Boundary Conditions (OBC)



Radiation u,v,T,S

Flather ubar,vbar

Chapman zeta