A ONE-WAY NESTED HIGH RESOLUTION CIRCULATION MODEL IN THE MALTA CHANNEL

Aldo F. Drago[1]* , Roberto Sorgente[2]

[1] Physical Oceanography Unit, IOI-Malta Operational Centre, University of Malta, Msida, Malta - adra1@um.edu.mt
[2] CNR-S2AM, c/o International Marine Centre, Oristano, Sardinia, Italy - sorgente@barolo.icb.ge.cnr.it

Abstract

A high resolution (1.2Km) eddy-resolving 3D prognostic numerical model based on the Princeton Ocean Model (POM) is used to simulate the seasonal circulation in the Malta Channel with perpetual year "climatological" forcing and with one-way nesting to an intermediate coarser resolution model (5Km) implemented over the Sicilian Channel area. The coupling between the two models is explained. The general results of this experiment are presented to assess the performance of the model.

Keywords: coastal models, circulation, Sicilian Channel

Introduction

One of the activities within the Mediterranean Forecasting System Pilot Project (MFSPP) consists in developing techniques and nested models to downscale the hydrodynamics to the shelf areas of the Mediterranean Sea [1]. The strategy is to downscale the large scale Ocean General Circulation Model (OGCM) (≈12.5Km resolution) flow field into an intermediate model with 5Km resolution. This intermediate model is implemented in the Sicilian Channel area [2]. The flow field from the intermediate model is further downscaled to the Malta shelf area with a resolution of 1.2Km. Both the intermediate and shelf model implementations are based upon the Princeton Ocean Model [3]. POM is a free surface, baroclinic, sigma-coordinate model that uses a time splitting technique to solve the depth integrated and the full 3D equations with different time steps. The vertical eddy viscosity/diffusivity parameters are calculated by an embedded 2nd moment turbulence closure [4]. The horizontal grid uses an 'Arakawa C' differencing scheme.

Model set up

The shelf model is implemented in the area spanning 13.8°E to 15°E longitude and 35.45°N to 37.1°N latitude, with a spatial resolution of 1/60° x 1/60° (71 x 107 grid points) and 15 sigma layers (bottom following) with logarithmic distribution near the surface. The model is closed at the northern boundary by the Sicilian coast and open at the western, southern and eastern boundaries. The average computational grid size is 1493m along latitude and 1853m along longitude. The U.S. Navy Digital Bathymetric Database 1 (DBDB1) with a 1/60° x 1/60° resolution is used for the computation of depth at each grid cell using bilinear interpolation. The maximum depth of 1054m to the SW of Malta limits the external courant time step to 4s. The shelf model is initialised from rest with T/S fields from the intermediate model.

Surface boundary condition

The monthly mean surface fluxes are taken from the climatological atmospheric forcing data set derived from the ECMWF Re-Analysis data set (ERA) for the period January 1979 to December 1993, initially mapped on a regular grid with a horizontal resolution of 1 degree for the Mediterranean Sea. The adopted momentum, heat and salt surface boundary conditions are:

$$k_M \frac{\partial \vec{u}}{\partial z}\Big|_{\eta=0} = \frac{\vec{\tau}}{\rho} k_H \qquad \frac{\partial T}{\partial z}\Big|_{\eta=0} = \frac{(Q_{sol} - Q_{up})}{\rho C_p} + \frac{C_1}{\rho C_p}(T^* - T)$$

$$k_H \frac{\partial S}{\partial z}\Big|_{\eta=0} = S(E-P) + C_2(S^* - S)$$

where τ is the wind stress, Qsol is the solar radiation, Qup is the upward heat flux, r is the density and Cp is the specific heat capacity at constant pressure. The heat and salt fluxes are relaxed to the monthly climatology given by the Med-6 data set, using a flux correction term with C_1=25W/m^2 °C and C_2=0.7m day^{-1} respectively. T* and S* are the monthly averaged climatological sea surface temperature and salinity, while T and S are the model first level temperature and salinity, respectively. The relaxation is that proposed by Zavatarelli *et al.* [5].

Lateral boundary conditions

The open boundary conditions are provided through one-way nesting to the Sicilian Channel Intermediate Model. The nesting of temperature, salinity and velocities (total and barotropic) is necessary in order to transfer values from the coarsely spaced grid to the finely spaced grid at the location of boundary region. The grid nesting ratio is 3. The ten-days averaged fields from the intermediate model are interpolated in space over the higher resolution grid and linearly in time at each time step through an off-line, one-way nesting. The internal and external normal velocities to the boundary are directly specified from the coarse resolution model. The tangential component velocities at the boundary are set to zero. In this specification the mass transport at the open lateral boundary is constrained to be equal to that prescribed from the coarse model at each respective open boundary

$$\int_{l1}^{l2}\int_{hhigh}^{\eta} U_{total}^{high}\, dl\, dz = \int_{l1}^{l2}\int_{hcoarse}^{\eta} U_{total}^{coarse}\, dl\, dz$$

where U is the coarse grid total velocity field, U is the interpolated velocity field, hcoarse and hhigh are the respective bathymetries of the coarse and high resolution grid model. The free surface elevation is not nested (zero gradient boundary condition), while an upstream advection is used for temperature and salinity: $\frac{\partial(T,S)}{\partial t} + U\frac{\partial(T,S)}{\partial x} = 0$

In the case of outflow through the open boundaries, temperature and salinity are prescribed from the coarse model.

Results

The ability of the model to reproduce a realistic circulation of the Siculo-Maltese shelf area is briefly examined. The main general circulation patterns are well reproduced with seasonal variability in both spatial extent and flow intensities. The model replicates the results of the intermediate model with additional mesoscale detail. This is exemplified by the velocity and temperature fields plotted in superposition for January and July in Fig.1 at 5m. During winter the temperature field is characterised by a sharp line of demarcation running in a SSE direction parallel to the axial orientation of the Maltese Islands. This is corroborated by satellite thermal infra-red images of the area. The surface velocity field is dominated by the Atlantic Ionian stream which is present throughout the year with significant seasonal modulation. During winter it follows closely the Sicilian coast up to 14.4°E longitude after which it detaches in a SE direction following the bathymetry. During summer this flow intensifies in magnitude and horizontal extent carrying a streak of relatively fresh water along its main axis; it spreads southwards and engulfs and flows around the Maltese Islands. The stream is accompanied by a persistent cyclonic pattern south of the eastern tip of Sicily which is enhanced during summer and occurs in association to density gradients produced by the intrusion of more saline water from the Ionian. At 280m the circulation is dominated by the westward flow of LIW to the south of Malta. This flow is most intense during winter and becomes slightly cooler during summer.

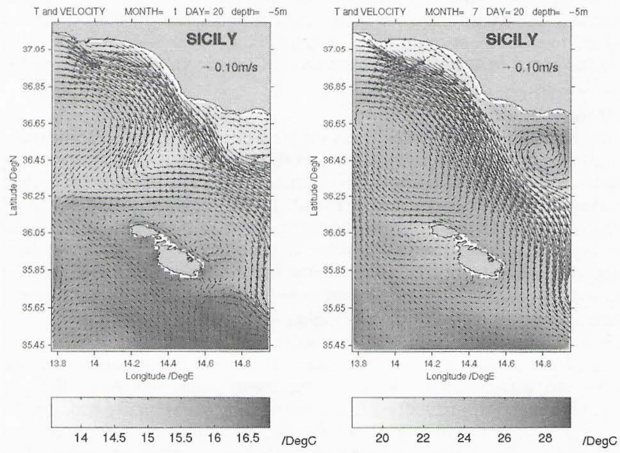

Figure 1. Model velocity and temperature at 5 mn during (a) winter, and (b) summer.

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