# Enhanced primary production over seamounts: A numerical study

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## 1. INTRODUCTION

It is well known that seamounts are hot spots of biodiversity. Seamounts provide structure for animals to live on, and the structure creates oceanographic effects that promote the production of food**.** A seamount, rising up out of the sea floor, has strong currents that frequently run over it, providing the animals living along its flanks with a constant supply of planktonic food.

These same currents also produce localized upwelling of water around the seamount. Nutrients like nitrates and phosphates, which are critical to the growth of phytoplankton, are lifted from the deep to the sunlit surface waters. These nutrients fuel an explosion of planktonic plant and animal growth.

Interactions between currents and seamounts can produce a variety of flow phenomena including localized upwelling, increased turbulence, and the formation of quasi-permanent, recirculating, anticyclonic currents known as Taylor cones.

In this paper we present a numerical study devoted to the Gorringe Bank , a volcanic seamount off the southwest coast of Portugal located at 36°30′30 N, 11°20′W (See Figure 1).

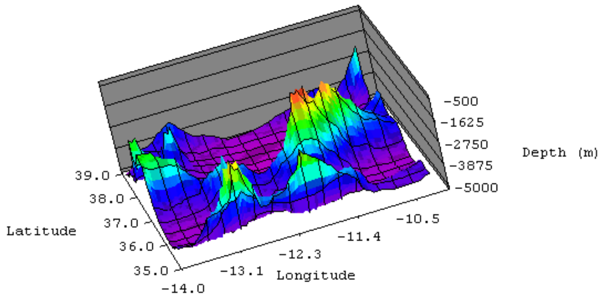

**Figure 1**: Bottom topography near Gorringe Bank. The eastern seamount is known as Ormonde Seamount while the western one is known as Gettysburg Seamount.

## 2. MATERIAL AND METHODS

### 2.1 – Model description

To study the circulation and primary production around Gorringe Bank we applied a 3D Ocean Circulation Model (*MOHID*). *MOHID* was developed at IST, Lisbon and is actually a system of coupled modules. For this particular study the hydrodynamic and the ecological modules were applied. Successful studies concerning ocean circulation were carried out in the past (e.g., Coelho, et al., 2002; Santos et al., 2002).

The hydrodynamic module of *MOHID* solves the three-dimensional primitive equations in Cartesian coordinates for incompressible flows. Hydrostatic equilibrium is assumed, as is as Boussinesq approximation. Density is calculated as a function of temperature and salinity by the equation of state published by Millero e Poisson (1981). The computed flow field transports salinity, temperature and other tracers using an advection-diffusion equation.

The ecological model included in *MOHID* is adapted from EPA, (1985) and pertain to the category of ecosystem simulations models i.e. sets of conservation equations describing as adequately as possible the working and the interrelationships of real ecosystem components

Franz *et al.* (1991) defined the general conservation equations for an idealized marine ecosystem model. Here we have adapted their definitions and establish a system that consists in five general state variables including phytoplankton, zooplankton, dissolved nutrient, organic matter in pelagic phase, organic matter in benthic phase, pelagic bacteria and benthic bacteria.

### 2.2 – Experimental Design

The model domain extends from 35ºN to 39ºN and from 10º to 14ºW. Horizontal grid spacing is 5 km in both directions. Bottom topography was derived from ETOPO5 by means of an interpolation for the model grid followed by smoothing with a five-point Laplacian filter. The bottom depth is then determined, using shaved cells (Visbeck *et al*, 1997). The model uses 23 vertical layers centered at constant z-levels at depths of 2.5, 7.5, 15, 25, 35, 50, 70, 90, 125, 200, 375, 750, 1250, 1750, 2250, 2750, 3300, 3900, 4450, 4825, 5000, 5087.5 and 5162.5 m.

Biharmonic heat, salt and momentum diffusion coefficients are set to $2x10^9$ $m^4s^{-1}$, a value equal to the one used by Batteen *et al* (2000) with a similar horizontal resolution.

The model is initialized from rest with mean annual climatological temperature, salinity and nitrate fields. It is then allowed to adjust to these fields in the absence of external forcing. The climatological temperature, salinity and nitrate fields are extracted from Levitus and Boyer (1994) and Levitus *et al* (1994) and are interpolated to the model grid before being smoothed using a simple cubic spline algorithm. The spin-up phase consists of a 1-year run using monthly surface climatological momentum fluxes derived from the near-surface analyses of the European Center for Medium-Range Weather Forecasts ECMWF (Trenberth *et al*, 1990). Surface temperature and salinity are relaxed to climatological data during the spin-up phase. After this period the model is run for 60 days using daily heat, mass and momentum fluxes from the ECWMF large scale forecast model for the months of July and August of 1994. The spatial resolution of the ECWMF fluxes was 0.5º by 0.5º. The data is interpolated spatially for the model grid and temporally for the model time step. During the entire run, temperature and salinity are relaxed to climatology by adding an adjustment term $[-A(z)(\phi-\phi_{c\lim})]$ to the right hand side of scalar equations ($\phi$ being the temperature or salinity, $\phi_{c\lim}$ its climatological value and $A(z)$ given by $A(z)=\frac{1}{\tau}\left[1-\exp(z/\lambda)\right]$, with τ=270 days and λ=1000 m).

Boundary conditions applied are described in Coelho et al., (2002).

## 3. RESULTS AND DISCUSSION

Results obtained show the typical circulation around seamounts, with a large anticyclonic eddy developing over it and with associated upwelling of deep rich nutrient waters. Figure 2 shows the velocity and nitrate fields at 100 m depth after 1 year and 60 days of simulation. It is clear that high nitrate concentrations are found very close to the Gettysburg and Ormonde seamounts. Associated to these high nutrient concentrations we also found a strong signal in Chlorophyll-a concentrations particularly in the flanks of the seamounts (see Figure 3 representing the Chlorophyll-a distribution at 40 m depth).

These results agree with observations made during the Summer at Ormonde seamount where a large community of brown and red algae were found at depths ranging from 36 to 60 meters. The observations suggested that the productivity levels observed could not be attained if production was nutrient limited (Measurements have shown that at these depths production is light limited) – see Santos e Coelho (2002).

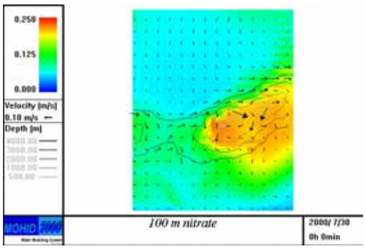

**Figure 2**: Velocity and Nitrate (in mg N/l) fields at 100 m depth.

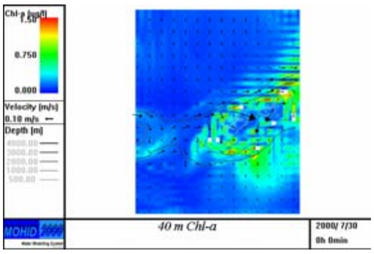

**Figure 3**: Velocity and Chlorophyll-a (in µg /l) fields at 40 m depth.

## 4. CONCLUSIONS

A simple model study was performed to test the hypothesis that high biomass concentrations and productivity levels were supported by upwelling of nutrient rich bottom waters. Model results have shown the existence of strong upwelling in the flanks of the seamount related with the anticyclonic circulation. On the other hand the coupled biochemichal model reproduced some of the patterns observed at least from the qualitative point of view.

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