3-D nested model for the Galician Shelf: Ecological response and interannual variation in the carbon export

Dag Slagstad

SINTEF - Civil and Environmental Engineering - Department of Coastal and Ocean Engineering
N - 7034 Trondheim, Norway

Task I.7 has the following objectives (short version):
Duration: Months 1-36
Objectives:

- Implement the existing SINTEF nested 3-D model in order to establish a coupled hydro-biological model, and investigate, together with IST, the optimal way of coupling these types of models.
- Simulate the response of the ecosystem to wind events,
- Calculate the possible variations of carbon export due to annual variation of wind forcing,
- Establish a mathematical model for meso-zooplankton in the Galician shelf to be used in the ecosystem model.

Deliverables due Month 24: *The 3-D nested, biophysical model established. First results from the 3-D ecological model discussed in relation to available data. Model description and results from first primary production, zooplankton and vertical flux test runs.*

Status: The biophysical model is established. A short description of the ecological model is included in this report and the first simulation results are shown below.

PI: Dag Slagstad, SINTEF

Activity year 2
The SINTEF hydrodynamic model was implemented for the Galician shelf during the first year of OMEX II-II. The SINTEF model comprises of a large-scale model having a grid point distance of 10 km and nested model domains. Two nested domains have been tested: One having a horizontal grid point distance of 2 km and one having a grid point distance of 3.3 km (Fig. 1). A relative large area has been chosen for the model set-ups. These areas will however be reduced in order to save computer time and thus be able to make more test runs. Both models have 23 horizontal levels of thickness (from surface to bottom): 8x5 m, 10 m, 4x25 m, 3x50 m, 100 m, 200 m, 400 m, 2x50 m, 1000 m, 2500 m.
In order to improve the available data sets for the bottom topography on the shelf, bathymetry maps have been digitised. Following maps from the Admiralty Charts and Publications, UK have been used:

3633	Islas Sisargas to Montedor	3634	Montedor to Cabo Mondego
3635	Cabo Mondego to Cabo Espichel	3636	Cabo Espichel to Cabo de Sao Vicente
1111	Punta de la Estrada de Bares to Cabo Finisterre		

The position of the digitised data values are shown in Fig. 1 (left).
For model setup, the 5-minute gridded elevation data (etopo5) from NOAA National Data Centres have been used in addition to the digitised data for the shelf.
The models have been run with the Levitus density fields and the sensitivity of the currents to the Galician shelf to change in the specified flow through the open boundaries has been investigated. Comparing the simulated flow field with observation showed relative good correspondence with a winter situation, but the important summer situation was in lesser agreement with the observations.
The simulated surface current had a marked poleward flow during the upwelling season whereas the observations show a general southward flow of this water mass. The reason for this is difficulties with the open boundary specifications. Work is now carried out in order to solve this problem in the near future.

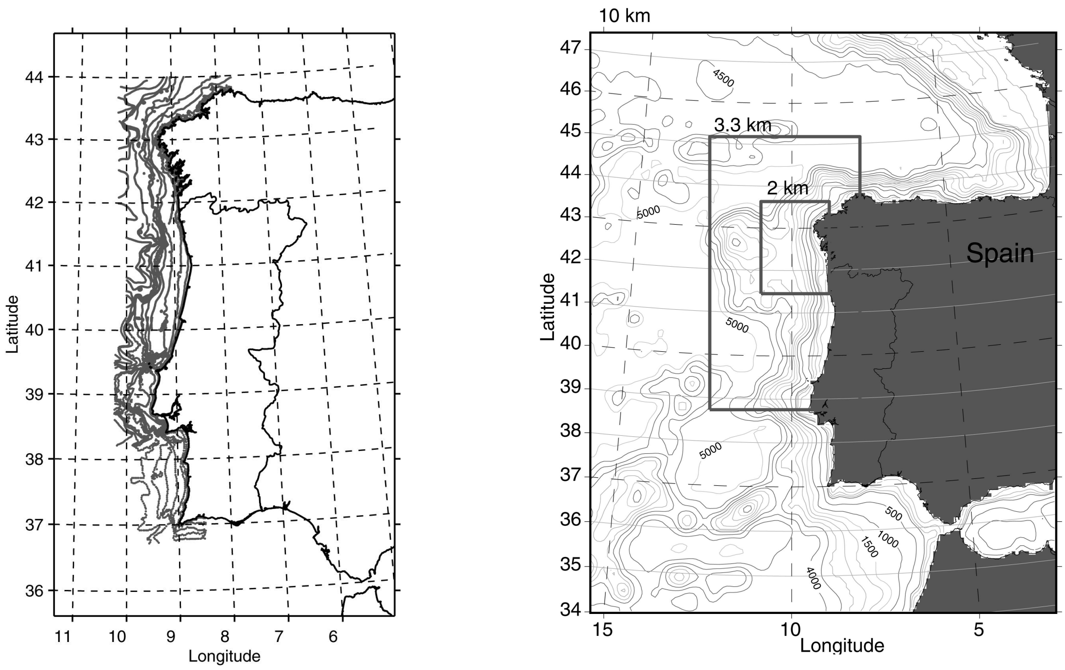

Figure 1. The position of digitised data values on the Iberian shelf (left) and Model domains (right) for the large scale and the nested models. The boxes off the Galician coast show the present domain for the nested (2 km and 3.33 km) models. The isobaths are shown for every 500 m in addition the 200-m isobath.

The nested (3.3 km) model does however successfully simulate filament structures on the Galician shelf (Fig. 2). It remains to verify details of their structure and to compare with real observations.

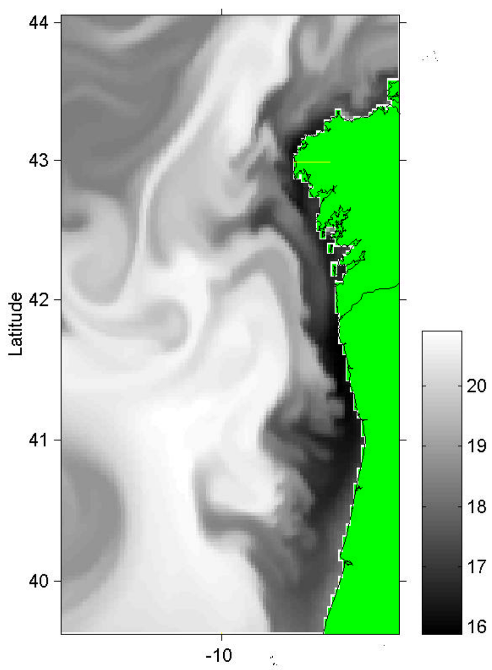

Figure 2 Simulated surface temperature, using wind forcing from August 1998.

Ecosystem model

The ecosystem model assumes that nitrogen and silicate are the potential limiting nutrients and consist of eight state variables (Fig. 3.). These compartments are: nitrate (NO3), ammonium (Na), silicate (Si), diatoms (Di), flagellates (F), microzooplankton (Mi), fast sinking detritus (Df), slow sinking detritus (Ds and mesozooplankton (Me) The basic unit used in the model is mmol-N m^{-3}.

The phytoplankton growth is a function of light, nutrients and temperature and will vary with solar elevation (i.e. the season, latitude and the time of the day) and position in the water column. A relationship between the solar elevation and photosynthetic available irradiance (PAR) has been established by using a model of Bird (1984). The attenuation coefficient, k, of light in the water column is described by Parsons et al. (1983):

$$k = \{k_w + 0.0088Chl + 0.054(Chl)^{2/3}\} / \bar{m}$$

where k_w (m^{-1}) represent the attenuation coefficient of pure, Chl is the concentration of chlorophyll *a* and $\bar{\mu}$ is the average cosine of the light field that equals 0.6 (Kirk, 1983).

Nutrient limitation on growth rate of diatoms and flagellates are calculated by a Michaelis-Menten equation. Nitrogen to support primary production is supplied from two sources, nitrate and ammonium and we assume that the limitation is the total nitrogen available (Fasham *et al.*, 1990). For diatoms, the nutrient limitation is the minimum of nitrogen, silicate or light limitation.

The loss of diatoms due to sedimentation of resting spores and aggregates is assumed to be caused by nutrient depletion. This, in nature, complex process is described by a formula given in Wassmann and Slagstad (1993) which transform diatoms into the compartment of fast sinking detritus

(1) $$S = (d_{mn} + (d_{mx} - d_{mn}))e^{-\min\{G_N^{Di}, G_{Si}^{Di}\}/d_g}$$

where S is the specific rate of conversion from diatoms to fast sinking detritus, d_{mn}, d_{mx} and d_g are parameters. A constant specific rate of dead diatoms and flagellates (often associated with respiration) are turned into slow sinking detritus.

The functional relationship of the photosynthetic active radiation (I_z) and the specific photosynthetic rate (f_I) is described by the following formula

(2) $$f_I = 1 - e^{-\alpha^B I_z / P_m^B}$$

where α^B is the chlorophyll *a*-normalised photosynthetic efficiency and P_m^B is the chlorophyll *a*-normalised maximum gross photosynthetic.

An apparent important grazer in the investigated area is microzooplankton. This functional group consists of several species, which vary in biomass during the period. Microzooplankton is usually assumed to feed on flagellates, but observations on diatom grazing have also been observed (Neijestgaard, 1994). Here we assume that microzooplankton prefer flagellates. Mesozooplankton consumes microzooplankton. Macrozooplankton feeding follows a functional relationship described by Carlotti and Radach (1996). Maximum grazing rate was set equal to 24% of body weight per day. A linear functional relationship between available food and grazing were used. On the other hand, if the maximum grazing rate at a given temperature cannot be sustained, the additional food is taken from diatoms. A linear functional relationship is used, starting from a lower feeding threshold and levels out at the critical concentration. Grazing on diatoms started at a lower threshold value of 10 mg C m^{-3} and a critical concentration of 100 mgC m^{-3} was set, whereas the corresponding grazing parameters for microzooplankton were 7 mgC m^{-2} and 20 mgC m^{-3}. The assimilation efficiency was equal to 0.7 and the excretion rate was 10% of the grazing rate + 1% of the mesozooplankton biomass per day.

Detritus is divided into a slow and a fast sinking component. The slow sinking component encompass non-assimilated material, dead bodies from microzooplankton and dead diatoms and flagellate cells, whereas the fast sinking component is made up by faecal pellets and dead bodies from mesozooplankton and sedimenting diatom cells (resting spores, aggregates, etc.). The fast sinking component has a sinking rate of 50 m d^{-1} and degradation rate of 0.33 d^{-1}, whereas the slow sinking component has a sinking rate of 1 m d^{-1} and a degradation rate of 0.05 d^{-1}.

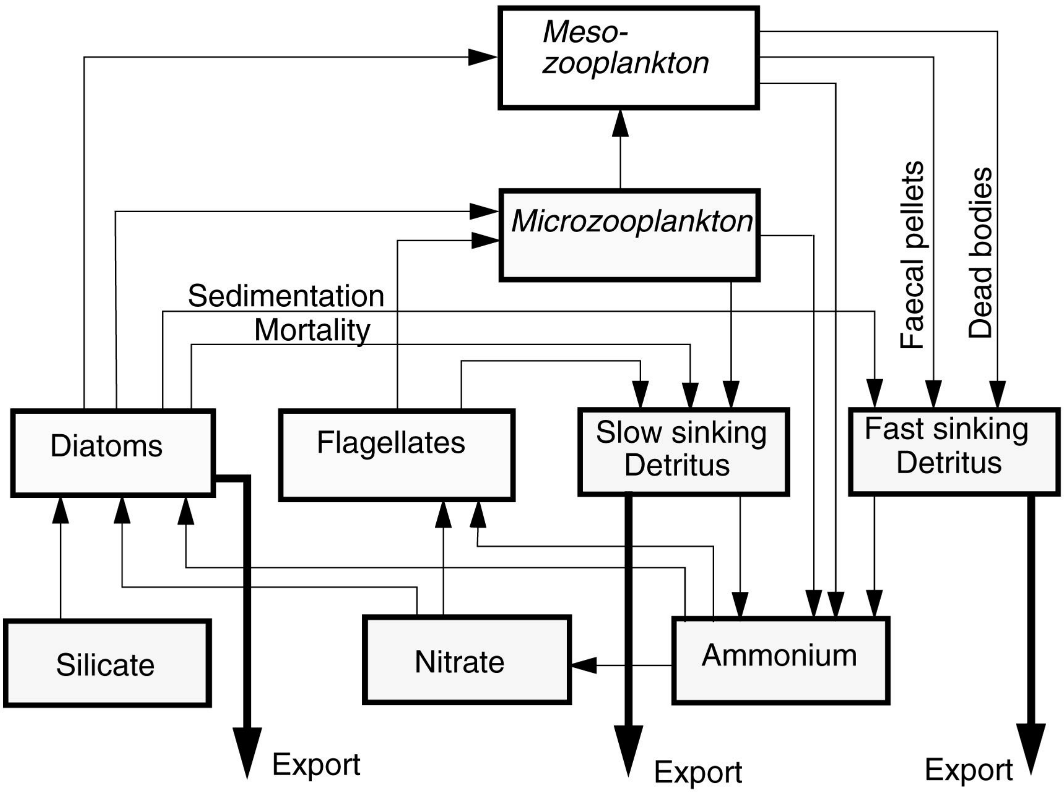

Figure 3 Ecosystem model structure

The structure of the ecosystem model was discussed during a workshop in Trondheim, February 1998. I was concluded that some of the compartments could be lumped together in order to reduce the computer requirements. Typical candidates are Nitrate and Ammonium, which could be aggregated to a "Nitrogen" compartment. We will however, lose the opportunity to calculate the new vs. total production.

Simulation experiments with the model show characteristic pattern with high production near the coast due to upwelling (Fig. 4).

Plans for the third year

The 3D hydrodynamic/ecological, nested model system for the Galician shelf is working. The hydrodynamic model needs some further adjustments of the open boundary conditions in order to simulate the surface flow properly. The ecological model needs more refinement (i.e. parameter adjustments) in order to mimic the ecosystem on the Galician shelf.

The following tasks will be performed in the coming year:

- The hydrodynamic model setup will be fixed towards the end of 1999 on order to concentrate on the biochemical simulations. The model will be verified against the data that is available for 1994.
- Establish the ecosystem model in a 1-D frame, which can be used for study of parameter sensitivity and internal dynamics. This model setup can be run on a PC and will be possible to run interactively during OMEX workshops.
- Field data have shown that mesozooplankton consist of *Acartia* spp. The mesozooplankton model will be modified according to these data.
- Run longer time simulations in order to make a budget of the carbon flux.
- Write the final report and publish the results

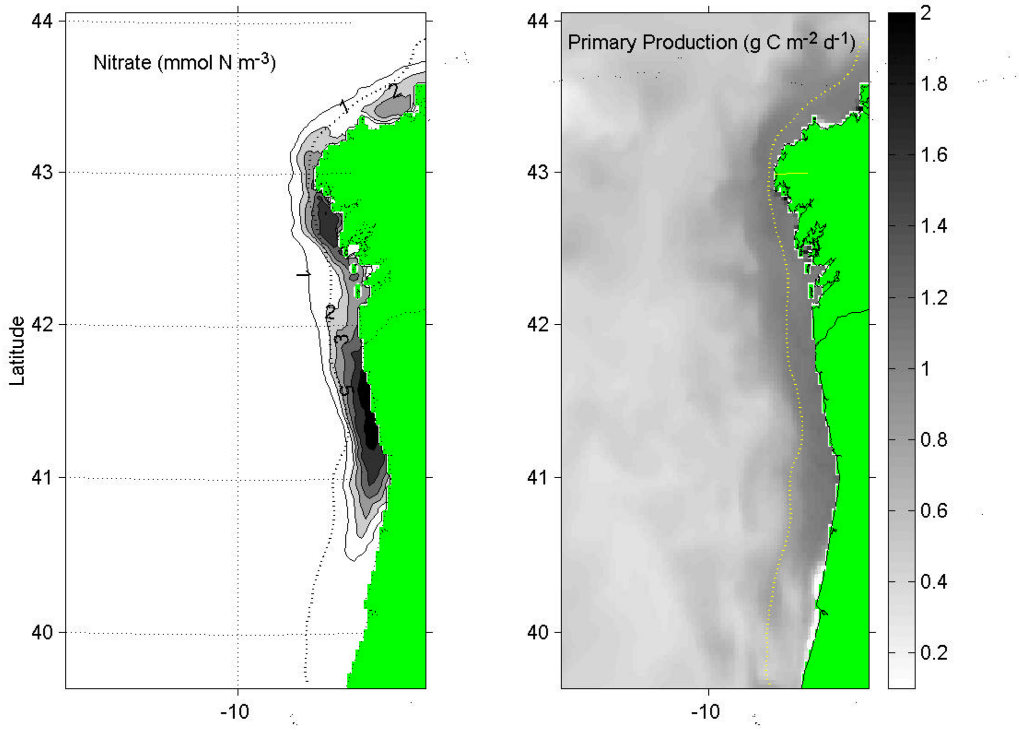

Figure 4 Simulated surface nitrate (left) and Primary production (right) during an upwelling event. The dotted line indicates the 200-m isobath.

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