MODELLING THE EFFECT OF FOOD WEB ON BIOGEOCHEMICAL PROCESSES

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Model structure. Modelling is still at the beginning. Its progress depends strongly on the state of description of the system, the dynamics of which is intended to simulate. The food chain concept is an important element of the biogeochemical models. Different trophic levels are usually considered. However, the knowledge of small organisms has progressed rapidly during the recent years. This part of the trophic web was ignored ten years ago mainly because neither the sampling and observations means were developped, nor the concepts elaborated. The food web structure has to be introduced in models.

The microbial food web which parallels the macrobial food web and allows the complete recycling of nutrients is necessary to explain most of the properties of regeneration of nutrients. Although model structure has to stay simple it should embed the major biological and chemical properties known from experimental studies. Interactions between biological, chemical and physical processes are important but the space and time where interaction develops is very often not at the scale selected for the design of the model.

At the other end of the food web the gelatinous organisms or large crustaceans are well described but their role is not well understood. These large organisms are scarse compared to bacteria so that their effect is not easily measured. They are important for the dynamics of many chemical elements either by their fecal pellet production or by their strong vertical migration. During some short period of time these large gelatinous organisms are relatively abundants (appendicularians, salps). The determinism of these blooms is not well understood but the strong effect of their feeding on particulate matter lay the task of developping the proper processes interactions on the modellers.

Different models have been developped to deal with food web which can be the base of simulations of segments of the geochemical cycle of some elements.

Processes to incorporate into models. A model should have a vertical dimension to accommodate the vertical passive transport by sinking or active transport by migration. Fronts which are the most productive in the Mediterranean sea are also the place where organic particulate matter is injected continuously in deep water. Hydrodynamic processes are forcing strongly biological processes in such areas. The second thing to improve in models is a set of biological functions which can represent the conditions of assimilation, storage, transfer of a chemical element in the food web. Factors regulating the ratio between the amout of a chemical element and biomass for different biological variables, as well as the function structure should be defined. Another important improvement will be in the speciation of chemical elements in the water and under the effect of the substances produced by living organisms.

The third important field of development is the scaling effect. In nature the small scale processes have an average effect on the mesoscale. Non-linearities are characteristics of biological processes and express couplings which underlay the processes effects.

Biomass of an element of the food web is usually considered as a single variable. It should have a more complex dynamics because cell cycle is important for unicellular organisms (it has been demonstrated for picoplankton) and cohort dynamic is basic for zooplankton. It is now clear that most of the food web structure and of the interactions have to be carefully reconsidered for each case study. The sub grid parametrization is an important step in the process of model design.

Scales, data acquisition. A model cannot be designed without any time and space domain which is characteristic of the phenomenon considered. Data are necessary to define this domain and also to calibrate and validate the model. Modelling is one of the method essential to understand a phenomenon. Observation and experimentation are two others. They have to interact and continuously exchange information and results.

Exernal forcings. The major problem in coupling physical processes with biological or chemical ones is that the scale of interaction is not well known at present. Vertical mixing, for instance, which can be of different types, keeps the biological system in a permanent initial state if it is strong enough and, in any condition, damps out nearly most of the dynamics of the biological system (limit cycle, multiple equilibrium points). However the effect of external variables, wind, calorific energy, river input, is usually assumed constant or slowly variable, although it is mostly short and intense.

It appears that, on one hand, the long term internal behaviour of a system is not well defined and on the other hand long term forcings are not very well evaluated, mainly because they are multidimensional.

In order to improve the biogeochemical models, it is necessary to continue on these lines and develop observations at sea and experimental work in parallel to models :

- on short term response because interactions are mostly at the small scale and we have the capacity to measure continuously or to experiment in mesocosms at these time scales;
- on long term behaviour because most of the interactions of climate and ecosystems are presumably developping also at this time scale.

INTERDISCIPLINARY MODELLING - PHYSICAL PROCESSES

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Physical processes consist of mixing and advection. The mixing processes can be divided into boundary and interior mixing. The boundary mixing, whether it is on the ocean surface or at the ocean bottom, is relatively well studied. Surface mixed-layer models are routinely used in study of upper-ocean thermal structures, and bottom mixed-layer models are often used in study of tidal mixing in shallow seas. In contrast, the interior mixing remains little understood. Modeling of interior mixing is usually based on simple *ad hoc* assumptions.

Applications of the one-dimensional mixed-layer models to the interdisciplinary modelling are quite common. The upper-ocean temperature and entrainment rate, predicted from surface mixed-layer models, can be used to calculate respectively the biological and chemical reaction rates and upward nutrient flux. Knowledge of the turbulence structure in the mixed layer can be used to calculate the trajectories of planktonic particles. Potential feedback from biology to physical process, such as the attenuation of optical depth by phytoplankton bloom, also has been explored.

While mixed-layer models are realistic, the general ocean circulation (three-dimensional advective processes) models are still quite primitive. The computer power is only marginal and the data base is lacking. Very few regional circulation models had ever been verified. So far, in interdisciplinary regional models, the flow fields usually are derived from simple idealizations. The common approaches use estimations from a well-known circulation pattern (such as the coastal upwelling circulation) or from the geopotential surfaces. The idealized flow patterns nevertheless are useful in providing mean flow trajectories for calculation of, for example, the dissolved and particulate material budget, the sedimentation pattern, and the larvae recruitment.

Embedded in the large-scale regional circulation are the mesoscale activities. These motions are marked by strong flow convergence and divergence. A well-known example is the frontal eddy and filament along a meandering current. The flow convergence and divergence can have major impacts on the biology. Local divergence (upwelling) will bring up nutrients, but, it also may cause larger advective loss. Local convergence will concentrate floating particles (food), but, it also may bring planktons below the photic zone. The complex interaction between frontal circulation and biological system can result in wide varieties of biological and chemical response.

We feel that a major opportunity in the interdisciplinary modeling is the study of biological and chemical system in mesoscale fronts. It is now feasible to describe the general convergence and divergence pattern in a frontal meander. Coupling such advective pattern to a biological model can be a useful tool to examine the observed biological heterogeneity. The model also can be used to explore the larger question of contributions of frontal system to the overall biological budget. Moreover, since the biology is sensitive to flow divergence, the advective processes themselves may also be quantified.

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