MODELING OF THE PLANKTON ECOSYSTEM OF THE AEGEAN SEA IN RELATION TO MIXED LAYER DYNAMICS

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ABSTRACT
A 1-D coupled hydrodynamic/biological model of the water column is applied in the Aegean Sea, in order to study the seasonal variability of the plankton ecosystem in relation to mixed layer dynamics. The MEDATLAS hydrological/biochemical database is used to determine the initial/boundary conditions and calibrate the coupled model with typical values for the Aegean Sea. The model reproduces the seasonal variations of the vertical structure of the primary/secondary production, in agreement with observations. Sensitivity analysis experiments showed that during the spring bloom period the initial nitrate content of the water column, the magnitude of which depends on the intensity of the winter turbulent mixing, determines the primary production level.

ΠΕΡΙΛΗΨΗ
Ενα μονοδιάστατο συζευγμένο υδροδυναμικό/βιολογικό μοντέλο της στήλης νερού εφαρμόστηκε στην περιοχή του Αιγαίου με σκοπό την μελέτη της εποχιακής μεταβλητότητας του πλαγκτονικού οικοσυστήματος σε σχέση με την δυναμική του στρώματος ανάμειξης. Η βάση υδρολογικών/βιοχημικών δεδομένων MEDATLAS χρησιμοποιήθηκε για να καθοριστούν οι αρχικές/οριακές συνθήκες και να παραμετροποιηθεί το συζευγμένο μοντέλο με τιμές χαρακτηριστικές της περιοχής του Αιγαίου. Το μοντέλο αναπαρίγγαγε τις εποχιακές μεταβολές της κατακόρυφης δομής της πλαγκτονικής παραγωγής σε συμφωνία με παρατηρήσεις. Πειράματα ευαισθησίας έδειξαν ότι κατά την διάρκεια της ευαισθητικής φυτοπλαγκτονικής άνθισης το μέγεθος της πρωτογενούς παραγωγής εξαρτάται κυρίως από την διαθεσιμότητα βρεττικών αλάτων, που σχετίζεται με την ένταση της τυρβώδους ανάμειξης κατά τη διάρκεια του χειμώνα.

Λέξεις κλειδιά: υδροδυναμική, βιολογικό μοντέλο, πλαγκτον, Αιγαίο
INTRODUCTION
Several experimental studies of the plankton ecosystem of the Aegean Sea revealed an extremely oligotrophic environment (e.g. Ignatiades et al., 2002). On the other hand, due to its complicated topography/geography and the large variability of the meteorological forcing, the Aegean Sea seems to be a site of intense eco-hydrodynamic interactions. The main purpose of the present study is to identify the relative importance of the key physical/biological processes and parameters controlling plankton productivity in such an oligotrophic area using an one-dimensional (1D - vertical) coupled hydrodynamic/biological model. The 1D model is calibrated using climatological seasonal biochemical/hydrological/meteorological data of the Aegean Sea, in order to describe the climatological (perpetual year) cycle of the mean vertical structure of biochemical parameters in the area. In particular, the impact of the variability of atmospheric fluxes and of the mixed layer depth on the evolution of primary/secondary production is investigated.

METHODOLOGY
We use a typical model of the Mediterranean plankton ecosystem (Lacroix and Gregoire, 2002), which we adapted to the plankton ecosystem of the Aegean Sea. The structure of the biological model is relatively simple, focusing on the lower trophic levels of the food web that are directly under the influence of hydrodynamic constraints, such as turbulent diffusion. We choose the dissolved inorganic nitrogen concentration (mmol N/m³) in order to describe the nitrogen cycle within the ecosystem. The model comprises of six state variables: phytoplankton, zooplankton, dissolved inorganic nitrogen (in the forms of nitrate and ammonium), particulate organic matter of phytoplanktonic origin (dead phytoplankton) and particulate organic matter of zooplanktonic origin (dead bodies and the faecal pellets of zooplankton).

Figure 1. Time variations of the near surface biomasses (mmol N/m³) of phytoplankton (PHY), zooplankton (ZOO), nitrate (NO3) and ammonium (NH4).
The sedimentation of biogenic particles (alive and dead phytoplankton, dead bodies and faecal pellets of zooplankton) is also considered. The hydrodynamic model used herein is a 1D version of the GHER 3D primitive equation model (Beckers, 1991). The temperature and vertical eddy diffusivity, calculated by the hydrodynamic model, are used by the biological model. The upper 300m of the water column are resolved with a vertical high resolution (2m). The biological and hydrodynamic processes formulation used in this model is described in Skliris et al. (2001). The coupled model is initialized and calibrated using mean seasonal profiles of the Aegean Sea derived from the MEDATLAS hydrological/biochemical database (MEDATLAS, 2002). Finally, the hydrodynamic model is forced by a “perpetual year” atmospheric forcing, using monthly averages of the 1979-1993 6-hour European Centre for Medium Range Weather Forecasts (ECMWF) reanalysis data.

RESULTS
After model calibration, a 4-year run is carried out, starting at Mid-November. After a 1-year adjustment period, the ecosystem reaches a quasi-equilibrium with a robust seasonal cycle of the state variables (Figure 1). The peak of phytoplankton bloom takes place during April followed by the zooplankton peak one month later. Phytoplankton consumes the high amounts of nitrate transported in the upper layer by the intense winter mixing. The phytoplankton stock in the surface layer is then depleted by nitrate limitation and grazing and a pronounced subsurface maximum is formed (Figure 2). The propagation of the phytoplankton maximum follows the depth of the nitracline and is also regulated by available light. In late summer the maximum decreases with time as a result of de-
creasing solar radiation at the nitracline depth. The model reproduces reasonably well both the magnitude and the propagation of the phytoplankton sub-surface maximum, in agreement with observations. A sensitivity analysis study was carried out, in order to estimate the relative effect of initial conditions of the state variables, the forcing constraints and the variation of the parameters on the evolution of the plankton ecosystem during spring. Results showed that in such oligotrophic coastal area the plankton ecosystem is mainly controlled by turbulent vertical transports of nutrients into the mixed layer in relation with the atmospheric forcing.

CONCLUSIONS AND PERSPECTIVES
A climatological coupled vertical hydrodynamic/biological model is applied in the Aegean Sea reproducing reasonably well the typical seasonal variations of the mean vertical structure of the biological production. In such oligotrophic area the plankton ecosystem is mainly regulated by nutrient availability in the mixed layer, in close relation with the intensity of the atmospheric forcing. Model validation is being carried out, using both in-situ and high-resolution satellite derived surface chlorophyll data, in order to define tuning adjustments and implement the results in a 3D ecohydrodynamic model of the Aegean Sea.

REFERENCE