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Seasonal and interannual variations in phytoplankton production at DYFAMED time-series station, northwestern Mediterranean Sea

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Abstract

Phytoplankton carbon assimilation has been measured near monthly using the ^{14}C method at DYFAMED France JGOFS time-series station from 1993 to 1999. Data were obtained using the "LET GO" technique, which allowed in situ injection of bicarbonate and incubation in enclosures at 10 depths. Incubation duration was 4 h around noon, from which daily production was estimated. The seasonal variation of the depth-integrated carbon assimilation exhibits a marked cycle. Maximum values reach 1.8 g $C\,m^{-2}\,d^{-1}$ in March or April; constant lower values were observed from August to January, in the range 100–300 mg $C\,m^{-2}\,d^{-1}$. The annual primary production vary in the range 86–232 g $C\,m^{-2}\,yr^{-1}$, in the upper range of older estimations. Primary production normalized to chlorophyll *a* shows maximum values in the period of oligotrophy. This increase of carbon assimilation rate per unit of chlorophyll *a* appears as linked to the period of phosphorus-limited ecosystem, and vertical distribution of taxonomic pigments suggests a possible role of cyanobacteria. Potential export production has been estimated from primary production data and Fp ratio based on pigments concentrations. These estimates (which imply biological steady state conditions) vary in a wide range, from 19 to 71 g $C\,m^{-2}\,yr^{-1}$. There is a decoupling between years with high potential export production and years with high measured particulate fluxes, which highlights the question of balance by resupply of the limiting nutrients and the role of dissolved organic carbon. A possible shift of primary production towards a more regeneration-dominated system is suggested for recent years. © 2002 Elsevier Science Ltd. All rights reserved.

1. Introduction

The determination of the magnitude of CO_2 fixation by phytoplankton (primary production) at seasonal and interannual scales, together with the carbon export to the deep sea, is a central objective of JGOFS (Brewer et al., 1986). Several ways to estimate the autotrophic carbon assimilation have been explored by direct or indirect methods. In oligotrophic waters, aside from the "classic" method of ^{14}C assimilation, the measurement of dissolved O_2 concentrations (Williams and Jenkinson, 1982) has been used.

The accuracy of the radiotracer method of Steemann-Nielsen (1952) was subject to debate (Gieskes et al., 1979; Jenkins, 1982; Jenkins and

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Goldman, 1985; Reid and Shulenberger, 1986). But the "clean" metal-free technique recommended by Fitzwater et al. (1982) overcame most of the problems and was recommended by JGOFS (1988). Numerous studies tried to reevaluate older primary production data and recent measurements were practically always higher than old ones.

Sournia (1973) reviewed the studies on primary production in the Mediterranean Sea. He concluded that data were uneven and sparse, mostly in coastal stations and with low temporal coverage, but gave yearly estimates comprised between 80 and 90 g C m^{-2} yr^{-1}. Since this review, some data have been obtained during cruises in the eastern and western Mediterranean Sea (Conan and Pujo-Pay, 1995; Estrada, 1996). Estimations of the primary production have been published based on CZCS data (Morel and André, 1991; Antoine et al., 1995). But data of primary production from measurements in the field are still very sparse and largely restricted to coastal zones.

As part of the French JGOFS program, the DYFAMED time-series station was occupied first in 1991. Primary production measurements during monthly cruises began in 1993. The objectives were to get a set of data with a sufficient temporal coverage and to reassess the productivity estimations in the western Mediterranean Sea; to evaluate interannual variations; to document processes of carbon cycle in this area where seasonal conditions vary from oligotrophy to mesotrophy.

2. Material and methods

The DYFAMED site is located 52 km off Cap-Ferrat, at 43°25′N, 07°52′E (Fig. 1) and at a water depth of 2350 m. The site is located in the central zone of the Ligurian Sea, NW Mediterranean Sea, and is protected from coastal inputs by the presence of Ligurian Current flowing along the Riviera coast. During monthly cruises since 1991, hydrological and biogeochemical parameters were monitored (CTD casts, nutrients, pigments, POC and DOC, etc.). All data are available through the DYFAMED Observatory data base http://www.obs-vlfr.fr/jgofs2/sodyf/home.htm and in the CD Rom joined to this special issue. The seasonal hydrological regime in the central NW Mediterranean Sea varies from winter mixing (February–January) to strong thermal stratification in summer to fall. Nutrients are depleted in the surface layer during summer oligotrophic situation and brought back to the surface layer during winter mixing. The general description of hydrological conditions and nutrient and phytoplankton variations is described in Marty et al. (2002).

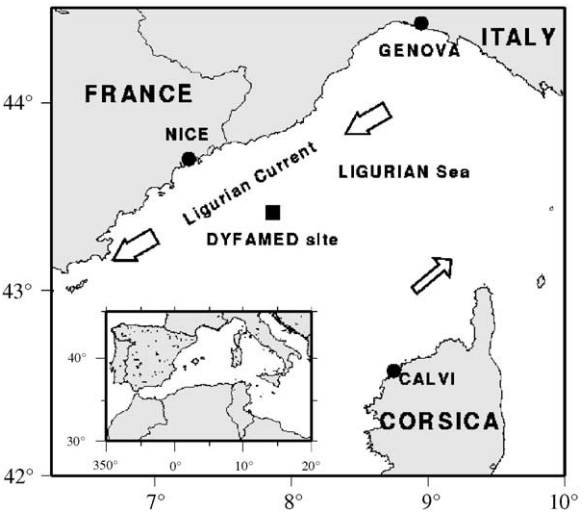

Fig. 1. Location of the DYFAMED site.

Measurements of carbon assimilation were performed during monthly cruises of the research vessel Tethys II from July 1993 using the ^{14}C radiocarbon technique (Steemann-Nielsen, 1952; Stickland and Parsons, 1972). Some authors (e.g., Carpenter and Lively, 1980; Fitzwater et al., 1982; Jenkins and Goldman, 1985) have highlighted potential sources of error associated with this technique, most of them linked to the stress of phytoplankton and to contamination during the sampling and incubation procedures. Data were obtained by using the LET GO apparatus (Dandonneau and Le Bouteiller, 1992), which solved most of these problems. This device allowed the sampling of water at predetermined depths and the injection of ^{14}C bicarbonate in a single

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