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VERTICAL CHLOROPHYLL DISTRIBUTION IN THE EASTERN MEDITERRANEAN AND BLACK SEA: QUANTITATIVE DESCRIPTION, CONNECTION BETWEEN PARAMETERS, STATISTICAL ESTIMATION

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ABSTRACT

From oceanographic studies carried out in the past twenty years it is clear that the mechanisms controlling biochemical cycle are not uniform throughout the World Ocean. Phytoplankton, the major component responsible for primary production in the sea, has a principal influence on biochemical cycling from local to global scales. A major objective in oceanography today is estimating the mean and the variance of primary production on a global basis. Biological variability is poorly sampled by classical shipboard operations and it does not allow more accurate estimations of phytoplankton biomass over large scale.

Satellite observations of ocean colour mode of the CZCS and SeaWiFS provide a synoptic view of phytoplankton pigment concentrations of a global scale at high spatial resolution with good time coverage. But these approaches are limited to provide information only one extinction depth. In the pelagic ecosystems of the ocean most part of phytoplankton occurs below this layer. This limitation have to be removed.

The first steps in this direction have been done by Canadian scientists Platt and co-workers. They proposed a generalised chlorophyll profile to be used in models of predicting primary production. French scientists Morrel and Berton have suggested that the shape of the pigment profile be related to the surface biomass and the vertical profile can thus be recovered from satellite data.

The aims of this investigation are (i) to provide mathematical representation of the vertical profile of chlorophyll (CHL) in deep part (depth >200 m) of the Black Sea and Eastern Mediterranean, (ii) to establish relationship of surface CHL concentration with integrated one and parameters used for the description of a vertical CHL profile, (iii) to give a statistical estimation to all researched relationships and (iv) to compare the quantitative characteristics of vertical CHL distribution in two interconnected basins.

In the present study data obtained in Ukrainian, Russian and Turkish cruises during last twenty years on the vertical CHL and fluorescence *in situ* (FLU) distribution in both seas were analysed and parameterised. The CHL profiles with as few as six data points were admitted for parameter estimation. These were found to be adequate to characterize the profile, provided that the data points were well distributed around the peak.

For parameterisation of one-modal vertical CHL or FLU distribution, which most frequently is encountered in deep-water areas of World Ocean the Gauss's formula was used in the following form:

$$C(Z) = B_0 + L * \exp [- (Z-Z_m)^2 / 2 * \sigma^2] \quad (1)$$

where the second term on the right-hand side of the equation (1) is a Gaussian curve (representing the CHL or FLU maximum) superimposed on constant for each separate profile background B_0, L - amplitude of a maximum and σ - reflection of width of the maximum background, equal 4σ.

The calculation of parameters of the equation (1) was carried out with use of a package of the applied computer program SigmaPlot for Windows. The statistical estimation of all relationships was carried out by the computer program ANOVA. As the integration characteristic of vertical CHL distribution the integrating of CHL in a layer of 0-150 m for the Eastern Mediterranean and 0-75 m for the Black Sea was applied.

The analysis of vertical CHL distribution in various deep-water regions of the Eastern Mediterranean has shown existence of two types of a profile: one-modal, for the description of which it was possible to use a Gaussian curve (1-st type), and quasi-homogeneaus uniform distribution of CHL concentration (C_q) from a surface up to some depth Z_q with the subsequent downturn of concentration up to a minimum (2-nd type).

In the Black Sea a little bit greater variety of vertical profiles was revealed, especially by the analysis of FLU profiles: in addition to first two in open part of the sea in spring months a CHL profile with a maximum of concentration on a surface (3-rd type) was found out and on FLU profiles, where discreteness of measurements was equal one m, two and three peaks of high values of fluorescence were found out. Such profiles made in some cases up to 10 % from total of the investigated set of FLU profiles.

Presence of maximum on CHL profile was defined by fulfilment of conditions (1):

$C_m / C_a > 1.3$ and $Z_m \neq 0$,

where C_m - maximal and C_a- average in a layer 0 - Z_m concentrations, Z_m - depth of a maximum of concentration. The value of 1.3 was taken according to results of Bio-optical Expert Group of the TU Black Sea Data Base, created in Erdemli (Turkey), which has established an error of CHL determination equal 30 % (P=0.05) from average concentration on the data of repeated determinations.

Fulfilment of a condition (2):

$0.7 < C(Z) / C_a < 1.3$,

where C (Z) - any and C_a the average concentrations in a layer 0-Z_q was the basis for classifying a profile as 2-nd type of vertical CHL distribution.

3-rd type of CHL profile needed performance of conditions (3):

$C_m/C_0=1$ and $Z_m=0$,

where C_m and C_0 - maximal and surface concentrations, Z_m - depth of a concentration maximum.

Type definition of vertical CHL profiles in the Black Sea allows to tell about seasonal specificity of profile type. So 1-st type is characteristic of summer, early autumn and later spring, 2-nd type- of winter and 3-rd is intermediate. It is to be noted also that the first type of profile is more universal, because it is observed in all seasons. This circumstance allows to observe the change of this profile during the whole year or differences between years for one month.

Opposite, in the Eastern Mediterranean the seasonal specificity of CHL profile is expressed much more poorly. For example, only in a southern part of the Adriatic Sea in March 1982 uniform vertical distribution of CHL was received. The concentration of pigment of 0.08-0.18 mg m^{-3} was observed from a surface up to 38-100 m, whereas in the Ionian Sea in December 1987 one-modal vertical CHL distribution was received on all stations. The truth, it is necessary to note that opposite of summer months the amplitude of peak was considerably less and the significant variations of Z_m were observed-from 28 up to 101 m. As a whole for Eastern Mediterranean much more variations of all parameters describing a profile were received, even within the limits of one month.

The close correlation between CHL and FLU received in the Black Sea (on the average r^2 was not lower 0.9 and cv was the order 30 %) lets to determine the parameters describing a vertical CHL profile more precise and to increase the reliability of connection between surface CHL concentration, which can be obtained from the data delivered by ocean color sensors, on the one hand and integrated concentration of a pigment and parameters describing a profile, on the other hand.

Character of vertical distribution of CHL or FLU and the values of parameters, describing it, reflect in general hydrophysical, hydrochemical and meteorological conditions as in the Black Sea as in the Eastern Mediterranean in different seasons. Type definition of vertical CHL profiles and determination of parameters, describing this distribution, allow to carry out a comparison of vertical distribution of pigment in different regions and seasons at a quantitative level and to estimate statistically variability of separate characteristics used for the description of a profile, such as amplitude, width and depth of CHL maximum or variability of vertical distribution of pigment as a whole.