SEASONAL VARIABILITY OF SPECTRAL SLOPE OF COLOR DETRITAL MATTER ABSORPTION IN THE DEEP PART OF THE BLACK SEA BASED ON SEAWIFS AND MODIS DATA SETS

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Based on multi-year satellite-derived color data sets, the spectral slope coefficient of color detrital matter absorption has been estimated. A seasonal variability of the spectral slope coefficient in the deep part of the Black Sea has been analyzed.

The direct measurement of absorption of the dissolved organic matter and, in particular, its spectral slope, below as *S*, is a precise and time-consuming procedure [1, 2]. The Black Sea direct measurement of *S* is rarely performed. Moreover, based on high-quality field measurements of spectral water-leaving radiance (or reflectance), the indirect estimations of *S* to make difficult because a number of input parameters of optical model remain unknown, and we have a few of such measurements [3]. The researchers give the various estimations of the *S* value ranging from 0.014-0.029 nm^{-1} for the Black Sea [4 - 7].

Our purpose is to obtain an estimation of the seasonal variation of spectral slope of color detrital matter absorption (sum of dissolved organic matter and detrital absorption, CDM) based on the multi-year satellite data set in the offshore part of the Black Sea (42.9-43.5N, 30.8-31.6E). The standard satellite-derived level-2 products of normalized water-leaving radiances, *nLw*, for SeaWiFS (GAC ver. 5.2) and MODIS-Aqua (LAC ver. 1.1) bands 1, 2 and 3 were used as baseline data. It is well known that the standard level-2/3 products in this spectral domain can be large errors resulting from current state of the atmospheric correction procedure [8, 9]. As in case of *in situ* measurements, it is difficult to simulate spectral water-leaving radiance because of incompleteness of input parameters of bio-optical model. Nevertheless, we have multi-year SeaWiFS/MODIS-Aqua data set in blue region of the light spectrum. In this paper, we attempt to use these two advantages of satellite data to define the seasonal shape of *S* value. We calculated the ratios of I_{412}=*nLw*(band 2)/*nLw*(band 1) и I_{443}=*nLw*(band 3)/*nLw*(band 2), below as index, from daily level-2 products at every pixel. Using special set of flags 8, 9, 20/21 to remove the artifacts of atmospheric correction algorithm [10], these values were averaged into data product over a spatial (2.5 km x 3.5 km grid) and temporal (two-week) domain.

The I_{412} index may be used to estimate the *S* value. If we neglect the absorption of phytoplankton and clear seawater compared with the sum of absorption of the dissolved organics and detritus in the blue bands, then, based on such rough assumptions, the *S* value is only a function of I_{412} index. The slope *S* was calculated as

$$S = 1/31 * \ln [I_{412} * F_o(412)/F_o(443)\ (443/412)^{n*}] \text{ in nm}^{-1}, \quad (1)$$

where $F_o(412)$ and $F_o(443)$ are the solar spectral irradiance in two bands (412 and 443 nm), *n** is an exponent of the ratio of total backscatter coefficients at bands 412 and 443 nm.

The plots for the slope *S* computed by (1) and its inter-annual approximation (2) are shown in Figures 1 and 2. The inter-annual approximation of the slope S was calculated as

$$S = 0.017 + 0.005 * \sin [2\pi\ (x+d)/12] \text{ in nm}^{-1}, \quad (2)$$

where *x* is a float in month, $0<d<3$ is a shift in month, which is a function of year.

Keeping in mind the limitations listed above, an expression (2) gives us an acceptable climatic shape of the slope S averaged throughout the lifetime of SeaWiFS and MODIS-Aqua sensors. The results weakly depend on *n** in a wide range from 1.5 to 2.5. Such behavior of *S* value means that there is a change in the qualitative composition of CDM in the seasonal cycle. Nature of high-frequency fluctuations of the value *S* in Fig. 1 and 2, calculated from satellite data, it is apparently the result of at least the combination of the two main factors: the phytoplankton absorption and atmospheric correction errors due to inadequate choice of aerosol models (for example, absorbing aerosol).

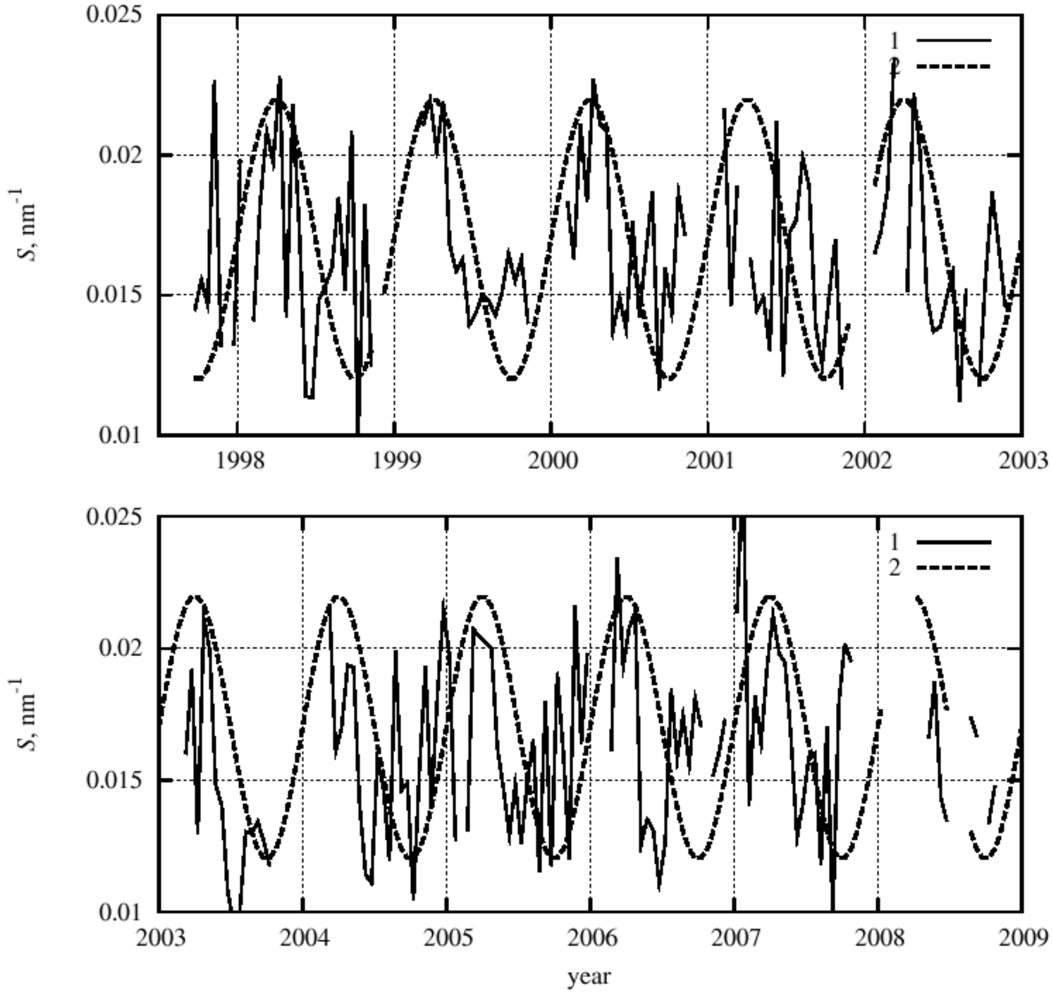

Figure 1. The slope S as time function calculated by the equation (1) using the SeaWiFS data from the deep part of the Black Sea (solid line, $n^* = 2$), and its climatic approximation (dashed line, equation (2), $d = 3$).

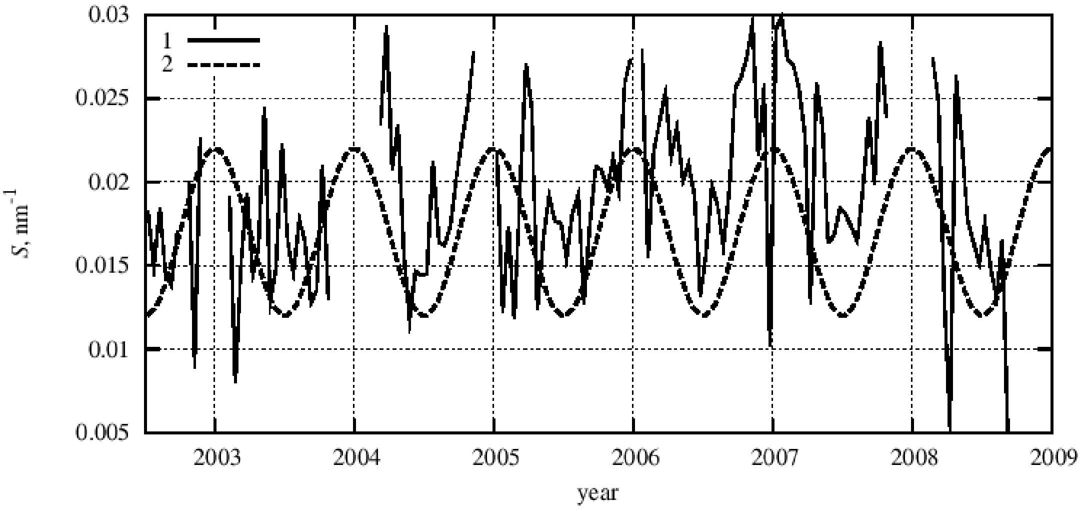

Figure 2. The slope S as time function calculated by the equation (1) using the MODIS-Aqua data from the deep part of the Black Sea (solid line, $n^* = 2$), and its climatic approximation

(dashed line, equation (2), $d = 0$).

It is clear, however, that the equation (1) can not be used for estimation of the *S* value during phytoplankton bloom. In particular, it is illustrated by the spring, 1998 for which phytoplankton bloom is a result confirmed by field measurements [11]. In addition, the phytoplankton bloom is easy separated in the index $\{I_{412}, I_{443}\}$ space during seasons (see Fig. 3*a*). We have a shift of spring points relatively of a line 3 in Fig. 3 when the absorption by phytoplankton is significant. This fact can be used as an indirect empirical evidence of diatom bloom in the open part of the Black Sea.

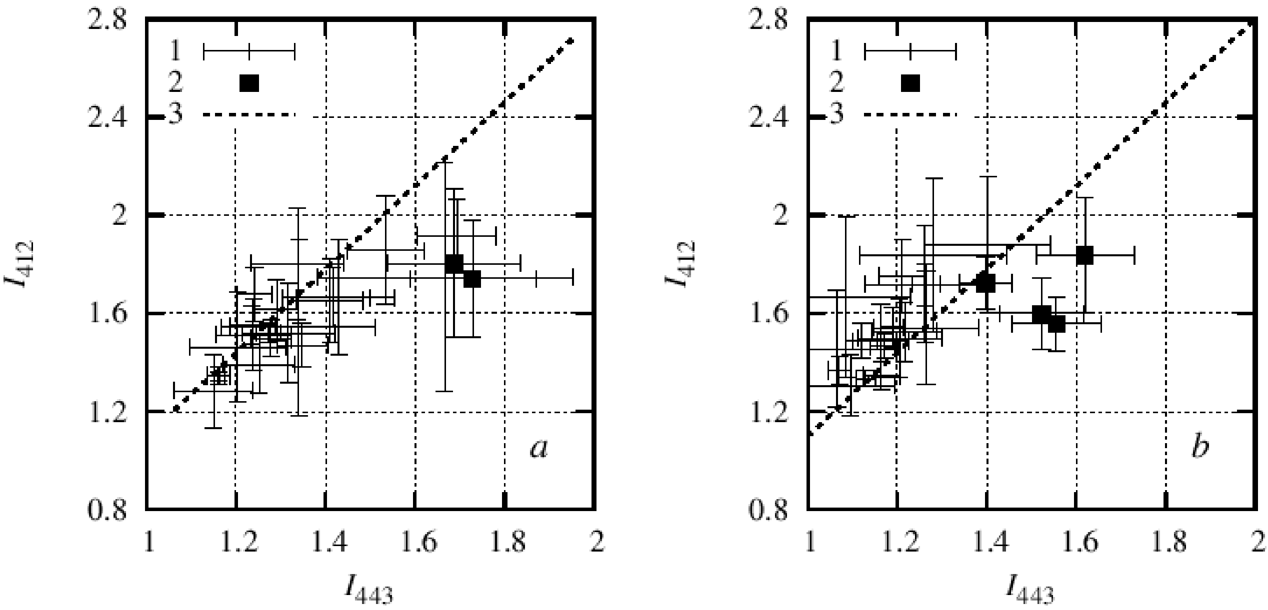

Figure 3. All (1) and selected-time (2*a* - March, 2*b* – January-March) two-week binned products of SeaWiFS sensor during 1998 (*a*) and 2004 (*b*) are shown in the axes $\{I_{412}, I_{443}\}$. The dashed line (3) describes the linear equation as $I_{412} = 1.7 * I_{443} - 0.6$.

Conclusions. The maximum and minimum values of $S \sim 0.022$ nm^{-1} and 0.012 nm^{-1} are obtained in winter-spring and in summer-autumn, respectively. Averaged over the lifetime of SeaWiFS and MODIS-Aqua sensors a seasonal shape of *S* in the deep part of the Black Sea is approximately described by the expression (2).

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