Variability of fluorescence of dissolved and suspended substances of biological origin in the Gdańsk Basin during the International Ecological Experiment "Sopot' 87"

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Fluorescence
Chlorophyll
Dissolved organic matter
Temporal variability
Spatial variability

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Abstract

Variability of fluorescence of chlorophyll and dissolved organic matter, temperature and light scattering were investigated with a submersible fluorometer at two stations in the Gdańsk Basin in spring 1987. It has been established that water motions played a key role in daily and short-term variability of these parameters. The correlation estimates have shown that chances to predict the distribution of these compounds on the basis of measurement of temperature or other abiotic factors were poor under experimental conditions. In order to improve the understanding of variability of ecosystem parameters in the Gdańsk Basin it is necessary to obtain a series of 3-dimensional distributions of oceanological characteristics covering the area under study.

1. Introduction

Variability of oceanological processes in the Baltic Sea has been investigated by many authors (Matteus, 1984; Karabashev 1987), yet there are no reliable data or a theoretical model permitting to predict the short-term or daily changes of the processes inside specified areas. The knowledge of the latter is of paramount importance in marine biological studies. They require not only an observation of temperature, salinity, and other abiotic factors, but also the determination of constituents of sea water, particularly those representing living matter or the products of its degradation. To meet this demand and support the International Ecological Experiment (IEE), scheduled for the spring of 1987, we have undertaken the measurements of fluorescence intensity of chlorophyll (FIC) and dissolved organic matter (FID), as well as temperature (T°C) and intensity of light scattering by particles in sea water (ISL), employing for the purpose a multi-channel submersible instrument. Measurements of this kind do not furnish precise data on chlorophyll concentration unless the instrument has been calibrated by a direct determination of the corresponding substances in sea water. These measurements provide, however, the highest space-time resolution and enable *in situ* observations of several variables in the same volume of water. The purpose of the present study was to estimate the variability of substances of organic origin during IEE and to draw the conclusions concerning the future ecological observations in the Gdańsk Basin.

2. Instrumentation and methods

A submersible fluorometer MSF was designed to record FIC, FID, ISL, and T°C as a function of hydrostatic pressure by vertical profiling in the depth range from 0 to 250 m (Karabashev, Khanaev, 1988). FID is excited with near UV radiation from a stroboscopic tube, FIC and ISL – with the visible light from the same source. Colour filters and light traps prevent crosstalk between optical channels. Output signals are stored, digitized and transmitted *via* a single wire cable on board of a research vessel. During IEE the instrument was interfaced to a Commodore computer and an XY-recorder. It permitted real-time plotting of profiles of fluorescence, scattering and temperature, as well as rapid preliminary data analysis and data exchange.

The measurements were carried out at anchor stations G-2 (54°50′N, 18°20′E) and Z (54°32′N, 18°56′E). The daily variability of FIC, FID, ISL, and T°C was studied at 3-hour intervals during 24 hours. These observations yielded the arrays of profiles B (st. G-2) and E (st. Z). Arrays C and D were obtained at station G-2 at noon and midnight and consisted of 6 casts separated by 8 – 10-minute intervals. Array H is similar to C but measured at station Z. Arrays A and K represent incomplete daily observations at st. G-2 and Z. The last cast at station G-2 and the first one at station Z together with casts at two drift stations situated between stations G-2 and Z "snapshot" the distribution of water properties along the track from G-2 to Z (array S). After interpolation with a depth step of 2 m, the profiles were used to calculate the statistical characteristic and to draw the depth-time or depth-distance distribution for the arrays.

The FID and ISL readings of the fluorometer are proportional to the concentration of light absorbing DOM and suspended particles in the Baltic waters (Karabashev, 1987). The FIC is proportional to the concentration of chlorophyll in sea water provided the phytoplankton composition and environmental factors remain unchanged. According to the observations of other IEE participants, these conditions were met at both stations. It allows assuming that FIC, ISL, and FID distributions obtained during IEE reflect relative distributions of chlorophyll, suspended matter, and DOM, respectively.

To facilitate a comparison of two-dimensional distributions, the isopleths of FIC, FID, and ISL were expressed in per cent of the corresponding maximum values for all the arrays of each variable. For the same reason we used the difference between the temperature estimate and the minimum temperature to plot the temperature distributions.

3. Results and Discussion

The profiles of mean values of FIC, FID, ISL, and T°C for arrays B, C, D, E, H are presented in Figure 1. The following features are worth mentioning. Surface waters at station Z were warmer by several degrees compared with station G-2.

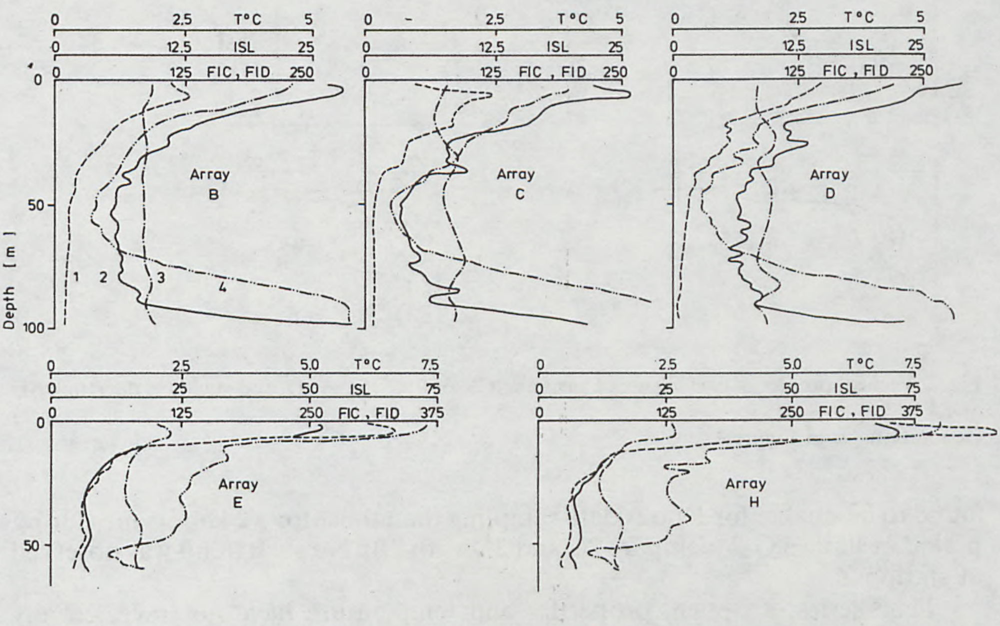

Fig. 1. Vertical profiles of mean values of FIC (1), ISL (2), FID (3) (in arbitrary units) and T°C (4), calculated for the arrays B, C, D at station G-2, and E, H at station Z

The temperature rapidly decreased beginning from the surface at station G-2 but at station Z there was a subsurface isothermal layer several meters thick. Most often the FIC and ISL values attained maxima at depths of 4 – 6 m and decreased down to 50 – 60 m at both stations, yet subsurface values of FIC and ISL were two times greater at station Z than those at station G-2. FID changed with depth independently of FIC, ISL or T°C at station G-2, while at station Z it revealed a weak subsurface maximum of FIC and ISL at the same depth. There was a strong maximum of ISL in the isothermal bottom layer at station G-2. Figures 1C, 1D, 1H provide an evidence that short-term variations of optical properties and T°C could have yielded mean profiles deviating significantly from the 24-hour average. The range of relative variability of FIC was the widest, and of FID – the narrowest among the measured optical properties. This observation agrees well with the data concerning open ocean (Karabashev, 1987).

The estimates of the coefficient of variation (CV) for FIC, FID, ISL, and standard deviation (SD) for T°C are illustrated in Figure 2. These estimates were

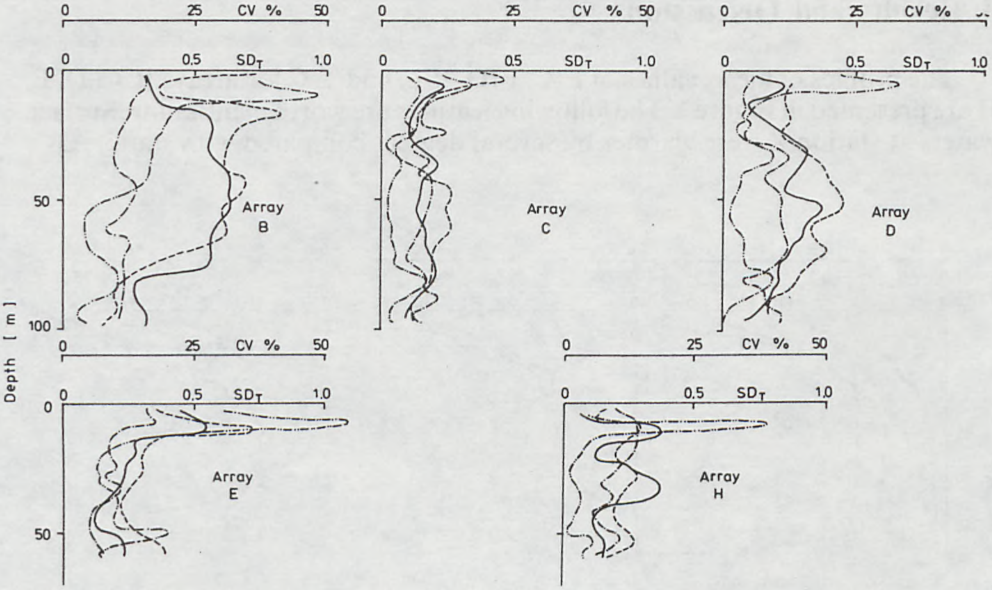

Fig. 2. Vertical profiles of coefficients of variation CV of FIC, ISL, FID, and standard deviation SD of T°C
Denotations as in Figure 1

found to be smaller for 1-hour data sampling than those for a 24 hours measuring period at station G-2 (compare 2C and 2D with 2B). No such trend was observed at station Z.

Time series of optical properties and temperature have not revealed any evidence of their diurnal rhythm at station G-2 (Fig. 3). This fact is most important in the case of FIC, since it is well known that in some areas of open

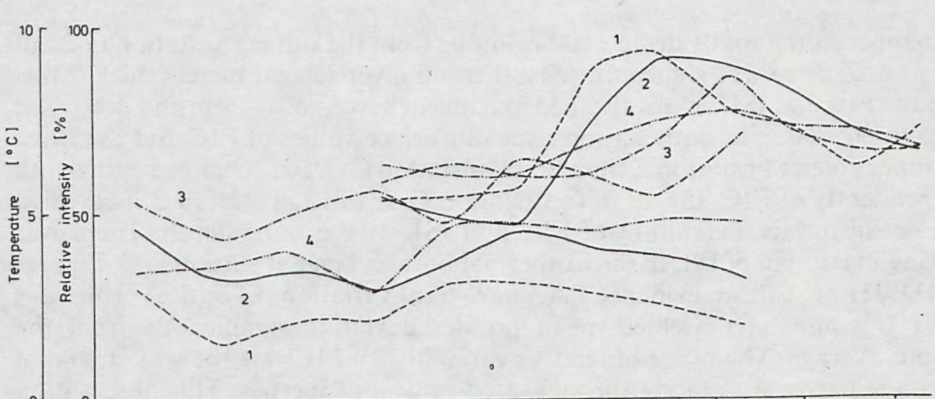

Fig. 3. Daily variability of FIC, ISL, FID (in % of maximum value), and T°C since morning (st. G-2) to evening (st. Z)
Denotations as in Figure 1

ocean a daily periodicity of chlorophyll fluorescence caused by light adaptation of phytoplankton may have a large amplitude and complicate the concentration dependence of FIC (Karabashev, 1987). At both stations FID and T°C slightly increased with time in the subsurface layer. The FIC reached a maximum in the morning almost simultaneously with ISL at station Z. In the case of light adaptation of phytoplankton, FIC reaches a maximum at midnight independently of the particle content in sea water. These findings, as well as a close correlation between FIC and the chlorophyll content in sea water, support the assumption on permissibility of using FIC measurements for the determination of the relative chlorophyll distribution during IEE.

A different behaviour of optical properties at station G-2 and Z may be better understood when their distribution along the track between the stations is considered (array S, Fig. 4). All the distributions reveal in this case the strongest changes in the middle of the track, where the sea depth decreased most rapidly. In the active layer all the variables reached maxima at the same place. Below this layer, the horizontal gradients of ISL and T°C were particularly large, which indicated the existence of a front-like structure in the middle of the track. It took only 6 hours at night to collect the data along the track. Therefore, it can be assumed that Figure 4 reflects a real space distribution of water properties. In this

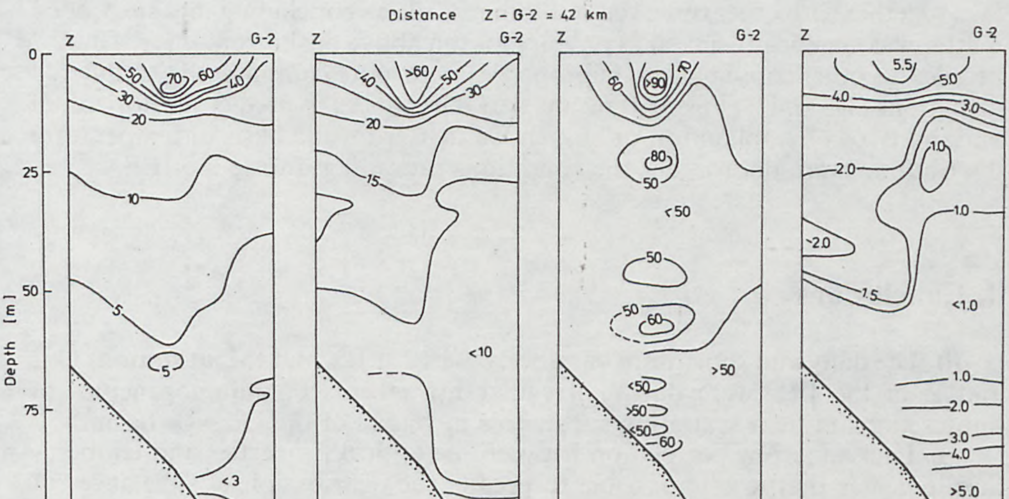

Fig. 4. Distributions of FIC, ISL, FID (in % of maximum value), and T°C along the 42 km track from station G-2 to station Z plotted for the array S

case, there is a strong possibility that the time variations of FIC, FID, ISL, and T°C at stations G-2 and Z were determined by the instability of the position of the front with respect to the stations.

Figure 4 shows that FIC and ISL changed along the track at depth down to 50 – 60 m in a similar way. Since the front motions played an essential role in the time variations of water properties. a rather strong correlation betweenn FIC and ISL at each of the stations can be expected. This assumption has been proved by the profiles of correlation coefficients (CC) calculated at 3-hour intervals. The CC profiles are presented in Figure 5. A strong positive correlation between FIC and

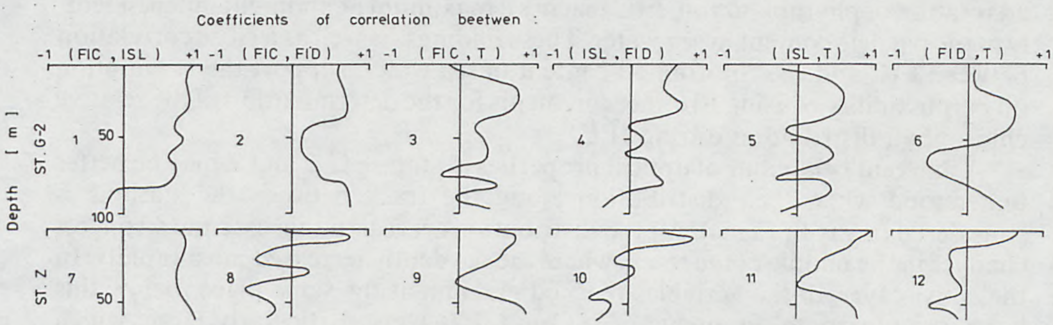

Fig. 5. Depth profiles of coefficients of correlation between optical properties and temperature at stations G-2 and Z

ISL can be noticed in all the cases except for a bottom layer at station G-2. This fact, together with other observed phenomena, allows concluding that suspended matter was genetically linked to phytoplankton above the bottom layer. The CC profiles for other combinations of properties were more complicated and differed at stations G-2 and Z (Fig. 5). It means that the chances to predict the horizontal variability of phytoplankton or suspended matter on the basis of temperature distribution were poor under the conditions prevailing during the IEE.

4. Conclusions

(i) The daily and short-term variations of FIC, FID, and ISL at stations G-2 and Z of the IEE were due to irregular movements of inhomogeneities of fluorescing and light scattering substances in waters of the Gdańsk Basin.

(ii) Lack of strong correlation between the optical properties and temperature indicates that it is impossible to predict the distribution of substances of biological origin on the basis of temperature distribution.

(iii) In order to understand the mechanism of variability of ecosystem features in the Gdańsk Basin it is necessary to organize future observations in a way allowing to obtain a series of three-dimensional distributions of oceanological characteristics covering the area under study.

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References

Antonov A. E., 1987, *Large-scale variability of hydrometeorological conditions of the Baltic Sea and its influence on exploitation of natural resources*, Gidrometeoizdat, Leningrad (in Russian).

Karabashev G. S., Khanaev S. A., 1988, *Underwater multi-channel fluorometer for marine investigations*, Zh. Prikl. Spektrosk., **49**, 3, 515–518 (in Russian).

Karabashev G. S., 1987, *Fluorescence in ocean*, Gidrometeoizdat, Leningrad (in Russian).

Matteus W., 1984, *Climatic and seasonal variability of oceanological parameters in the Baltic Sea*, Beiträge zur Meereskunde, 51, 29–49.