International Council for the Exploration of the Sea

C.M.1986/ C:9
Hydrography Cttee

Year-to-year variations in spatial distribution of oxygen surplus in the Norwegian Sea

by

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ABSTRACT

The data on value of oxygen supersaturation of the surface layers and depth of occurence of lower limit of supersaturated layer in June 1979-84 are presented. It is shown that the spatial structure of oxygenated layer differs depending on position of frontal zone and water heat content.

RESUME

Les données sur le degré de la sursaturation des couches supérieures de l'eau par l'oxygène et sur la profondeur de la position de la frontière basse de la couche sursaturée join 1979-84 sont présentees. On a montré que la structure spatiale de la couche saturée par l'oxygène présente une différence essentielle, selon la position de la zone frontale et le contenu de chaleur des eaux.

INTRODUCTION

During the photosynthesis of algae in vegetation period a surplus of dissolved oxygen was produced in the surface layers of the ocean. The observed surplus was an integral for the period remainder of all produced oxygen except for expenses for breathing of organisms, oxidation of organic substance and evasion in atmosphere. The value of this surplus and also the depth of its distribution may serve with known assumptions an indirect characteristic of intensity of organic substance production for a period preceding observations (from beginning of vegetation to the moment of observation). When analysing seasonal variations of oxygen surplus in the Norwegian Sea it was established earlier that the annual maximum of supersaturation was observed in June. The results of studying the characteristics of oxygenated layer (value of supersaturation and depth of occurrence of supersaturated layer) relative to the main peculiarities of hydrological conditions (position of frontal zone and heat content of active layer) are listed in the present paper.

MATERIAL AND METHODS

Observations over dissolved oxygen made during the standard surveys of the Norwegian Sea in June 1979-84 were used as initial data. The oxygen was determined by Winkler method. The value of supersaturation of water with oxygen (ΔO_2 ml/l) was estimated as excess of observed concentration (O_2^D ml/l) over saturated one (O_2 ml/l) at the given temperature and salinity ($\Delta O_2 = O_2^D - O_2$).

Dissolvability of oxygen was determined according to International Oceanographic Tables, t. 2, at each standard depth. The

mean weighted values of oxygen surplus were calculated for supersaturated layer at each station. The depth (D) with a relative content of 100% ($\Delta O_2 = 0.0$) was assumed to be a lower limit of this layer.

A comparative analysis of spatial distribution of oxygen surplus in the layer was made with the charts of ΔO_2 ml/l distribution and topographic charts of 100% isoxygene.

RESULTS AND DISCUSSION

The analysis of the long-term variations of water temperature in the 0-50 m and 0-200 m layers of the East-Icelandic and Norwegian Currents at 65°45'N (Table 1) showed that during 1972-82 the temperature was characterized by a negative trend. The eastern (relative to the long-term mean) position of frontal zone was typical to 5 out of 6 considered years and western position - to 1981 (Shevchenko and Isaev, 1983, 1984, 1985). A relative increase in heat content of the surface layers was observed in central part of the Sea in June 1981 and 1980 (Shevchenko and Isaev, 1984).

A general view of occurrence depth of supersaturated layer in the Norwegian Sea in 1979-84 was a mosaic of stretched in the direction of current patches (Fig.1). The depth limits ranged from 17 to 200 m with 25 to 120 m prevailing, the mean depth - about 75 m. The maximum depths were recorded, as a rule, in the western marginal and Jan-Mayen areas, the minimum ones - on the Norwegian shelf. The experimental depth (239 m) was registered in June 1981 in the centre of anticyclonic gyre (69°20'N 2°E).

In all years the depth of this layer increased from east to west. In the western Norwegian Sea the maximum depth of supersaturated layer was observed in the years of increased heat content of

Table 1. Trends to temperature variations in 1972-82 at 65°45'N

Waters	Layer	Trend
East-Icelandic Current (11°-5°W)	0-50	y = 3.95-0.066x; (-0.66)
	0-200	y = 2.09-0.026x; (-0.26)
Norwegian Current (1°45'-5°E)	0-50	y = 8.02-0.046x; (-0.46)
	0-200	y = 6.55-0.071x; (-0.71)

active water layer (1980-81) and the minimum one - in abnormally cold 1983. In the same year there was noted the shortest spatial extent of the layer deeper than 75 m, its easterly limit passed in central part of the Sea along 7°W.

In 1981 and 1982 it was located along 5°W and in 1979, 1980 and 1984 occupied the easternmost position - about 2°W. Accordingly, in 1979, 1980 and 1984 the frontal zone was displaced eastward while in 1981 it occupied the westernmost position for the period considered and in 1982 it was feebly marked in central part of the Sea (Shevchenko and Isaev, 1983, 1984, 1985). In summer 1983 the East-Icelandic Current was extensive and pronounced. Its waters spread far southeast and to central part of the Sea where great negative temperature anomalies were found (Shevchenko, 1984) which did not seem to favour the intensive development of phytoplankton in mixed waters. Therefore, in 1983 the area of supersaturated layer of above 75 m was the least.

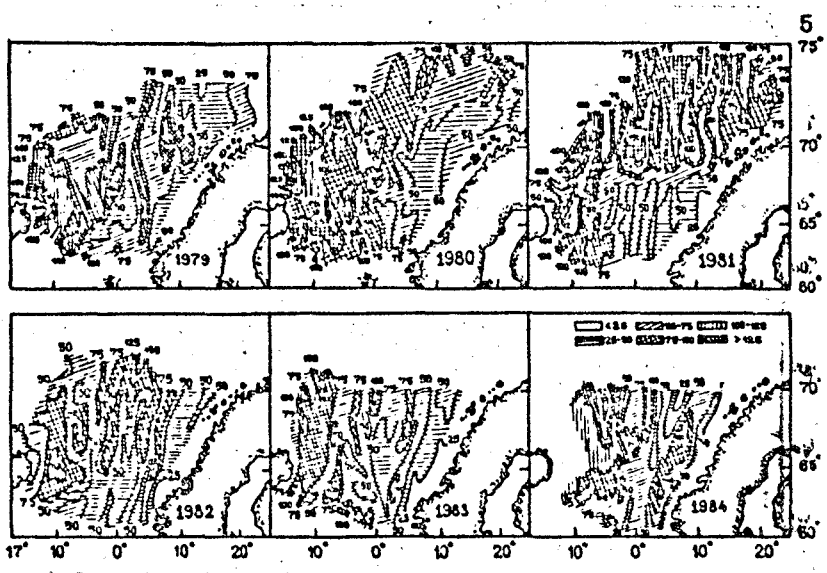

Fig.1 Depth of occurence of supersaturated layer in the Norwegian Sea in June 1979-84.

The value of oxygen surplus varied in this layer on the average from 0.15 to 1.3 ml/l. The extreme values - 0.11 and 1.7 ml/l - were observed in June 1983 in the mixed (maximum) and Atlantic waters. The comparison of ΔO_2 distribution and intensity of supersaturated layer showed that, as a rule, in zones of considerable (above 0.5 ml/l) oxygen surplus the depth of this layer did not exceed 55 m in the Atlantic and 90 m in the mixed waters. With increasing of the layer depth above 100 m the ΔO_2 decreased to 0.3-0.2 ml/l. According to data from the 1980 survey the correlation coefficient between these values was equal -0.34 (6_r = 0.08).

In 1979 the maximum value of supersaturation was observed in the mixed waters near the Jan-Mayen Island and it constituted 0.92 ml/l . The oxygen surplus above 0.5 ml/l was found in the East-

Icelandic waters northeast of Iceland (D=70 m) and Faroes Islands (Fig.2), and in Atlantic waters north of 70°N (D < 50 m).

In 1980 the maximum oxygen surplus never exceeded 0.70 ml/l and was the least for a considered series of years. The maximum values were observed in mixed waters east of Iceland (D≈90 m) and in the Eastern branch (D≈ 27 m).

In 1981 the maximum values of O_2 were higher - from 0.70 ml/l in mixed waters along 5°W (D≈ 50 m) to 1.20 ml/l east of the Jan-Mayen Island (D≈70 m).

In 1982 the oxygen surplus in the East-Icelandic Current waters was the highest for all considered years and reached 1.22 ml/l at 67°30'N. Along the section Langanes-Jan-Mayen the mean value of ΔO_2 made up 0.80 ml/l. Northeast of the Faroes Islands the oxygenation nearly doubled compared to 1980, 1981 and 1983. The minimum values of ΔO_2 (less than 0.3 ml/l) were observed in

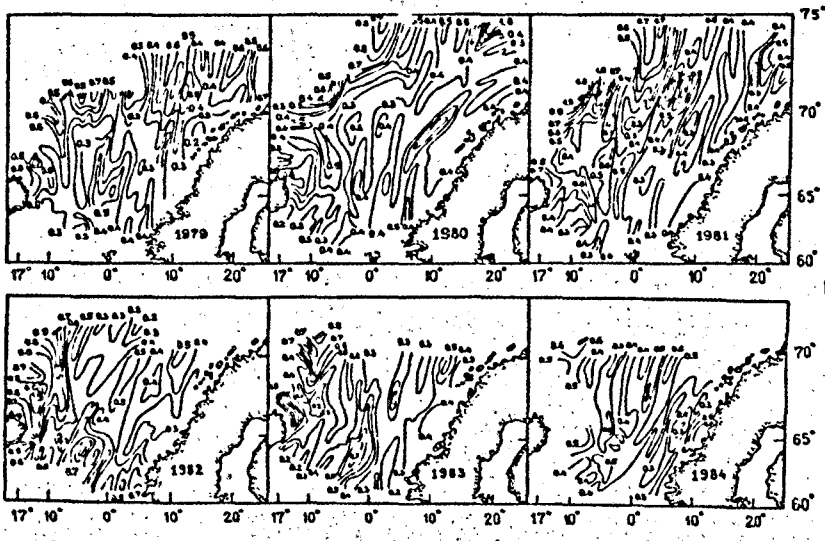

Fig.2 Distribution of oxygen supersaturation value (O_2 ml/l) in the Norwegian Sea in June 1979-84.

a rather limited area of the Norwegian Shoal.

In 1983 small zones of maximum supersaturation were found in the mixed waters east of Iceland (0.63 - 1.7 ml/l, D = 71-86 m), south of the Jan-Mayen Island (to 0.90 ml/l, D = 79 m) and north-east of the Faroes Islands (0.85 ml/l, D = 50 m).

In 1984 there were no observations in western part of the Sea. In the area surveyed (Fig.2) the maximum oxygen surplus did not exceed 0.79 ml/l. Like in 1983 the area of zones of increased (above 0.5 ml/l) oxygen surplus was small. As is seen from the foregoing the highest values of oxygen surplus were mainly observed in western marginal area of the Sea during the whole period under review. The major blooming zones were also registered there. All this resulted from synchronism of the June survey and annual maximum of phytoplankton vegetation in the East-Icelandic Current waters (Vinogradova, 1970).

The highest for the considered period values of photic layer oxygenation registered in June 1982 in the western marginal area were accounted for by mass blooming of phytoplankton (Degtereva et al., 1985). At that time there was observed a good water stratification due to intensity of the East-Icelandic Current in deep layers and considerable (twofold higher than in 1981) radiation heating of the surface waters (Ergakova, 1985).

In June 1982 the mean supersaturation in waters of the south-western Norwegian Sea (67°30' - 63°30'N 14° - 5°W) exceeded by 0.12 ml/l the 1981 level. But so far as in 1981 the depth of super-saturated layer was approximately by 25 m greater than in 1982 one may consider that the oxygen production in 1981 was maximum of all considered years. This conclusion was corroborated by data of

hydrobiological investigations (Plekhanova, Soboleva, 1982), as a result, there was registered an early onset of biological spring in the west, mass development of phytoplankton throughout the Sea and the highest for 1979-83 biomasses of zooplankton the intensity of development of which was surely connected with a mass development of phytoplankton.

The oxygen surplus fields were characterized in 1979, 1982 and 1983 by increased values in central part of the Sea (62°-66°N 0°-6°W). The highest supersaturation values in this zone were 0.64 ml/l in 1979, 1.02 ml/l in 1982 and 0.85 ml/l in 1983. The maximum area of the zone was in 1982 (120 miles by latitude), the minimum - in 1983 (50 miles). The intensification of the East-Icelandic Current and frontal zone in the south of the Sea resulted evidently in appearance of this zone (Shevchenko, 1983, 1984).

The zone like that was not observed in a period of weakening of the East-Icelandic Current in 1980 and 1981. During the displacement of frontal zone westward in 1981 there was clearly observed the division of the area by oxygen surplus into western (with higher supersaturation) and eastern parts; the boundary of the 0.4 ml/l isoxygene passed near zero meridian. The comparison of the oxygen surplus in western and eastern parts of the Sea at 65°45'N showed that the maximum supersaturation was observed in Atlantic waters in 1980 and 1984 while in western Sea waters - in 1981 and 1982.

In June 1981 the position of frontal zone was western and in June 1982 - "vague", i.e. there was noted the decrease of horizontal gradients. The hydrological conditions in 1980 and 1984 were characterized by an intensification of Atlantic waters while the intensity of the East-Icelandic Current remained the same and the

heat content of the surface layer increased. Hence, the intensity of organic substance production grew in Atlantic waters with intensification of frontal zone in the years of relative heat content increase and in the East-Icelandic waters - with weakening of the zone or its westward displacement.

The presence and distributive pattern of zones with small oxygen surplus (less than 0.3 ml/l) in the Norwegian Current and in mixed waters of the western part of the Sea should be referred to peculiar features of water oxygen regime in years of intensification of the East-Icelandic Current (1979, 1980 and 1983). Their most considerable expansion was observed in abnormally cold 1979 and 1983 with the decreasing heat content of the Norwegian Current waters. The local peculiarities of thermal regime in 1980 and 1982 involved the reduction of these zones compared to 1979. In 1980 with weakening of the East-Icelandic Current there increased the warm advection of eastern branch of the Norwegian Current which evidently favoured the more intensive development of phytoplankton securing the greater water oxygenation. In 1981 the water heat content of active layer in the western branch was near the norm and higher than in 1979 which was also followed by disappearance of zones with small oxygen surplus.

The comparison of oxygen distribution and that of Calanus at different ages (Plekhanova and Soboleva, 1982) showed the following: in mixed waters of central part of the Sea where oxygen surplus ranged from 0.38 to 0.66 ml/l the highest zooplankton biomass and high nauplii abundance were noted in 1979. The maximum nauplii abundance was succeeded by supersaturation of the upper 30 m layer to 0.7 ml/l off the northeastern coasts of Iceland.

In June 1980 the maximum nauplii abundance was registered in Atlantic waters in the area from 64° to 67°N between 2° and 3°E with higher, compared to ambient, values of supersaturation - 0.41-0.53 ml/l. In the Eastern branch waters copepodite stages I-V prevailed in size and the oxygen surplus did not exceed 0.40 ml/l.

In 1981 the highest for these years biomass and abundance of zooplankton were recorded in Atlantic (along 3°E) and mixed (along 5°W) waters with supersaturation of 0.3 and 0.5 ml/l respectively. In Atlantic waters east of zero meridian where ΔO_2 was on the average 0.35 ml/l (from 0.26 to 0.39 ml/l) copepodite stages IV-V of Calanus made up the bulk of abundance while farther west, in mixed waters, the earlier stages I-III and nauplii prevailed at ΔO_2 being not less than 0.5 ml/l. In a zone of maximum nauplii abundance (64-66°N 2-3°W) the oxygen surplus was 0.54-0.66 ml/l.

In 1982 though distribution of total seston biomass was quite another the high values of supersaturation corresponded to high abundance of nauplii: in the northeast of the Sea - 0.43-0.56 ml/l, in the west of the East-Icelandic Current - 0.87-1.22 ml/l. The value of oxygen surplus was smaller (from 0.39 to 0.25 ml/l) in a zone of mass development of copepodite stages I-V of Calanus.

Thus, the high (above 0.5 ml/l in mixed and above 0.4 ml/l in Atlantic waters) values of oxygenation were indicative of the onset of biological spring. Despite the thermal characteristic of a year the certain degree of water oxygenation correlated to certain state of zooplankton population.

On the whole, in June with the increase of water heat content and moderate distribution of the East-Icelandic Current the oxygen production will be higher throughout the Sea than in abnormally cold years with maximum intensification of the East-Icelandic Current.

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Подп. в печ. 30/VI 1986 г. Формат 6Cx84 I/I6 Заказ 305
Объем 0,75 п.л. Бесплатно Тираж 190

Ротапринт ВНИРО
I07I40. Москва, Верхняя Красносельская, I7