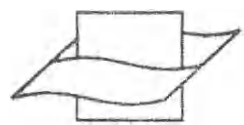


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# INVESTIGATIONS ON OPTICAL PROPERTIES AND WATER-MASSSES OF THE SOUTHERN NORTH SEA

by

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## CONTENTS

1. Introduction . . . . .	532
2. Optical properties investigated . . . . .	533
3. Results of the observations in 1966 . . . . .	535
4. Some results of the observations in 1967 . . . . .	544
Acknowledgements . . . . .	551
Summary . . . . .	551
References . . . . .	552

## I. INTRODUCTION

For the study of the circulation and the mixing processes in the sea, the use of indicators characterizing different water masses, such as temperature (or potential temperature) and salinity, is well known. That the (potential) temperature of the water may be used for this purpose, is due to the fact that in the deep sea this property may be regarded as conservative, that is, it only varies as a result of the mixing of water masses of different (potential) temperatures. For the water near the sea surface, where heat exchange with the atmosphere occurs, this is only approximately true, and it is therefore clear that certainly for a shallow, vertically well mixed sea area such as the southern North Sea the temperature as an indicator of water masses is of limited value. Therefore, there is a need for the study of the use of other properties, either chemical or physical, as indicators of water masses. These properties should be conservative, or at least, it is required that they can be considered as such for a certain time interval. It is mainly for this reason that studies of optical properties of sea water have been undertaken by the section of oceanography of the Royal Netherlands Meteorological Institute. Various authors have already published results of investigations of this kind in the North Sea or in other sea areas. Several of these investigations will be mentioned in the following study, which gives the results of some cruises made in the years 1966 and 1967. These cruises were made early

in the year, in the months of February and March, because it was thought that in this time of the year the chance of complications in the interpretation of the measurements by a high concentration of plankton would be minimal.

In the following the terms water mass and water type will be used in accordance with SVERDRUP *et al.*, (1942), a water mass being generally the mixture of two or more water types, which are defined by means of single values of the indicator properties. This use of the term "water type" therefore differs from that of LAEVASTU (1963).

## 2. OPTICAL PROPERTIES INVESTIGATED

The following properties of the water have been investigated, apart from the usual temperature and salinity determinations:

- a.* Natural fluorescence
- b.* Attenuation of red light
- c.* Difference between attenuation of blue and of red light

A few remarks on these properties are given here.

*a.* Natural fluorescence. — The natural fluorescence of sea water, arising from dissolved organic substances, has been the subject of several studies by KALLE (1949, 1956, 1957, 1963) and POSTMA (1954). The possibility of changes of the amount and the properties of fluorescent substances in the sea by biological and chemical processes should be kept in mind but, still, under various conditions fluorescence has been used with success as a water mass indicator.

Measurements of fluorescence were carried out with a Turner fluorometer, in a broad spectral region between about 400 and 600 m $\mu$ . As the study of the use of this property is done in close co-operation with investigations on the same subject, carried out by S.B. Tijssen of the Netherlands Institute for Sea Research, and as it is intended to publish results of these investigations later on, we shall not discuss in detail the use of fluorescence as an indicator, but we shall mainly use results of our measurements as far as they appear to be useful for the interpretation of the other observations.

*b.* Attenuation of red light. — This property is related to the scattering by suspended particles. A paper on the relation between attenuation coefficient and concentration of suspended matter, based on previous investigations in the North Sea and the Wadden Sea has been published

earlier (OTTO, 1966). The measurements dealt with here are made with the same instrument, a beam transmittance meter, and the attenuation coefficients are defined in the same way,  $C'_R$  being defined by

$$C'_R = \frac{1}{L} \log \frac{F_{L, \max}}{F_L},$$

where  $F_L$  is the radiant flux measured,  $F_{L, \max}$  is the maximum value of  $F_L$  found during the series of observations concerned and  $L$  is the path length of the light beam in the water.

From the fact that suspended matter is the main cause of the light attenuation in the North Sea it is clear that the presence of particles that are temporarily in suspension may complicate matters in such a way that the use of the attenuation coefficient as an indicator of water masses is rendered impossible. Upstirred bottom material as well as particles which otherwise do not necessarily have a quantitative relationship with the composition of a certain watermass, as for instance plankton, may therefore give rise to important difficulties.

JOSEPH (1953) has given relations between suspended matter and light attenuation in the surface layer for different water masses in the southern North Sea. His measurements indicate the presence of a suspension mainly consisting of very small particles with an effective optical diameter of the order of a few microns (POSTMA, 1961). This suggests that the suspension is so fine that settling is negligible and that it behaves as a dissolved substance and therefore might be useful to characterize water masses. Light attenuation values have in fact been used for this purpose in a more or less qualitative way by KALLE (1937a), using observations made during January 1935 and February 1936 in the southern and central parts of the North Sea, respectively.

During our previous investigations, however, relations between suspended matter and light attenuation could either not even be shown to exist or, if present, gave considerable larger optical diameters for the suspended particles, indicating the presence of plankton or upstirred sediment (OTTO, 1966). This was one reason why the later investigations were carried out during the winter months (as was also the case with JOSEPH's observations) in order to meet with smaller plankton concentrations in the water.

The influence of the other disturbing agent, the upstirred sediment, may be minimized by considering only the near surface values of the attenuation.

*c.* Difference between attenuation of blue and of red light. — This is thought to be a measure of the concentration of dissolved organic

substances that absorb light in the blue part of the spectrum, the so-called "yellow substance" or "Gelbstoff". The concept on which this assumption is based is that the attenuation of red light is largely caused by scattering, while that of blue light is caused by both scattering and absorption of light.

The results were obtained by comparing the measurements made with the beam transmittance meter, alternatively using a red colour filter (Schott RG2) and a blue filter (Schott BG12). The difference between the values of  $C'_R$  for blue light and for red light has been called  $\Delta C'_R$ .

The properties of "Gelbstoff" have been studied by KALLE (1937*b*, 1949, 1956, 1961). The difference between the attenuation of blue and of red light as an indicator of "Gelbstoff" has also been used by KREY (1952). Instead of blue light, ultraviolet light also can be used, but this asks for special provisions for the measuring equipment (JOSEPH, 1949, 1950).

It has to be remarked, however, that the difference between the attenuation coefficients for two spectral regions is no more than a rough measure of the content of "Gelbstoff", as selective absorption by particles also may play a rôle. JERLOV (1955) has indicated a way by which it is possible to correct for this effect. He calculates a correction factor  $K$ , which takes into account the selective absorption, by comparing the data of series of observations from vertically homogeneous water masses. This method also has been used by MALMBERG (1964). However, it appeared to be impossible to apply this method with success to our observations, probably because relatively large vertical variations in the composition of the suspension occur in such a shallow sea as the southern North Sea.

### 3. RESULTS OF THE OBSERVATIONS IN 1966

The observations were made from February 28 till March 4, 1966, in the Southern Bight of the North Sea on board of the fisheries research vessel "Willem Beukelsz". During part of the cruise the wind was fairly strong, which prevented the use of the beam transmittance meter at several stations.

The distribution of salinity and temperature at the surface are given in figures 1 and 2. It is clear that the temperature and the salinity distributions are not similar, which demonstrates the restricted value of water temperature as an indicator.

The surface salinity chart clearly shows the well-known features of the distribution of this property in the Southern Bight. The water of high salinity comes from the English Channel, the less saline waters to the

SURFACE SALINITY

W. BEUKELSZ 28/2 - 4/3 1966

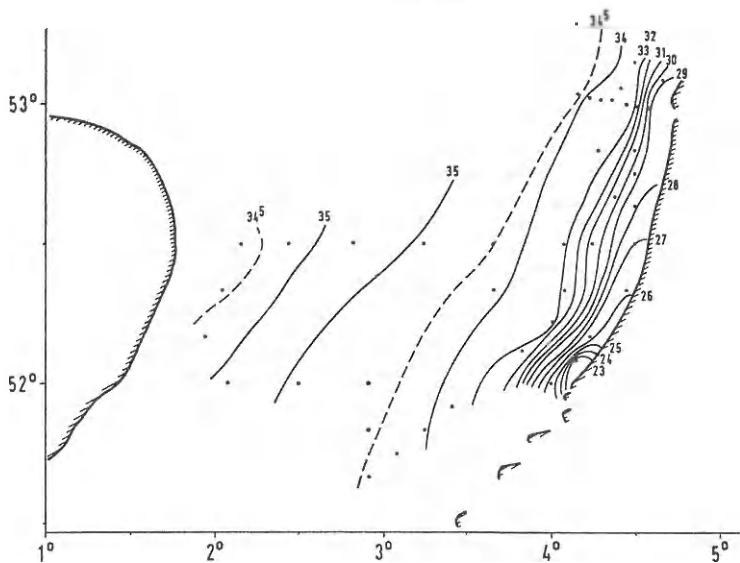


Fig. 1. Surface salinity of the Southern Bight of the North Sea, February 28 till March 4, 1966.

SURFACE TEMPERATURE

W. BEUKELSZ 28/2 - 4/3 1966

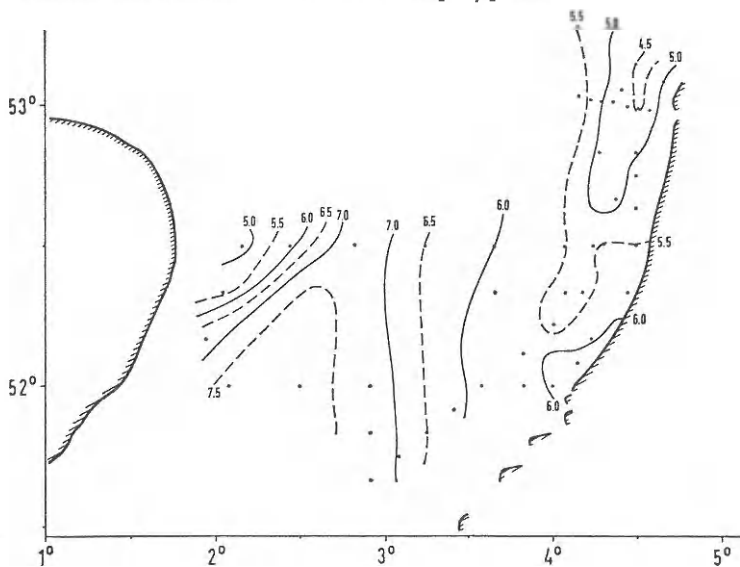


Fig. 2. Surface temperature of the Southern Bight of the North Sea, February 28 till March 4, 1966.

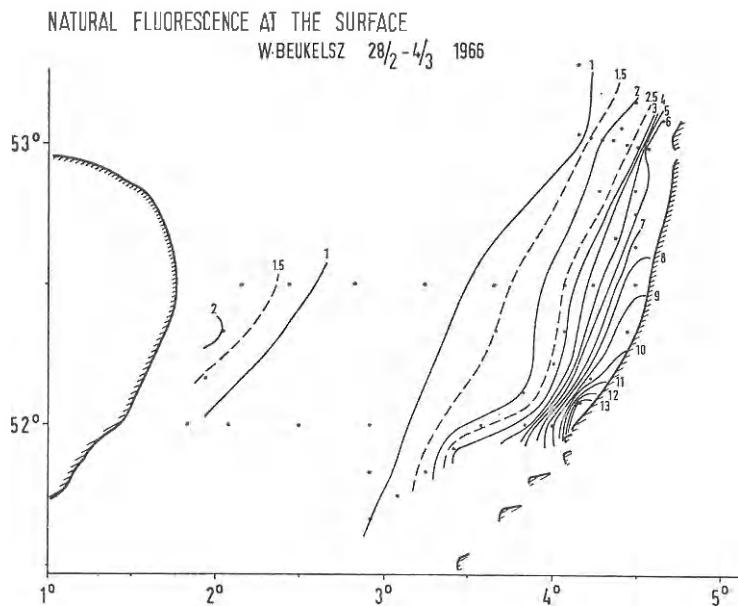


Fig. 3. Natural fluorescence at the surface of the Southern Bight of the North Sea, February 28 till March 4, 1966.  
1 fluorescence unit = 2.1 mFl.

east and to the west are mixtures of saline water with river water mainly from the Rhine, the Meuse and the Scheldt on one hand, and of the Thames on the other hand.

The distribution of the values of the natural fluorescence is given in figure 3. The unit is arbitrarily chosen, but can be related to the unit mFl, introduced by KALLE (1963) by

$$1 \text{ fluorescence unit} = 2.1 \text{ mFl.}$$

The pattern presented in this figure closely resembles the salinity pattern which indicates the possibility of using fluorescence as a tracer in this case. If the observations are plotted in a fluorescence-salinity diagram, in which each simultaneous observation of both properties is represented by a point, the observations made on the English side and those made on the continental side appear to be arranged along two different straight lines. These lines apparently are characteristic for the two water masses, which we here shall call "English Coastal Water" (ECW) and "Continental Coastal Water" (CCW). It should be noted in this connection

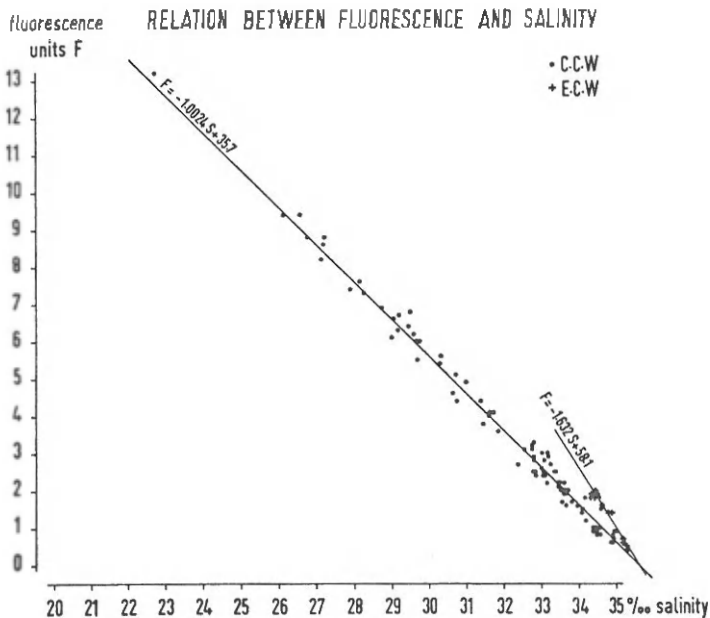


Fig. 4. Fluorescence-salinity relation. Points: Continental Coastal Water; crosses: English Coastal Water. 1 fluorescence unit = 2.1 mFl.

that our use of the term "water mass" here excludes the presence of a third water mass between those two, such as the Channel Water which is mentioned by several authors (see *e.g.*, LAEVASTU, 1963). Instead we shall later on introduce a water type, the "Straits of Dover Water".

The relations between the fluorescence  $F$  (in mFl) and salinity  $S$  (in ‰) are given by (regression of  $F$  over  $S$ ):

$$\text{ECW: } F = -3.43 S + 122 \quad (18 \text{ observations, correl. coef. } 0.98)$$

$$\text{CCW: } F = -2.10 S + 75 \quad (128 \text{ observations, correl. coef. } 0.99)$$

(see fig. 4).

Turning next to the values of  $\Delta C'_R$ , as representing the concentration of "Gelbstoff" (which, as well as the fluorescent substance, is of organic nature and is probably closely connected with the latter), we give in figure 5 the surface values of  $\Delta C'_R$ . Although only part of the region is covered by attenuation measurements, the pattern of salinity and fluorescence distribution can be recognized. Again, we find a linear relation for both water masses (regression of  $\Delta C'_R$  over  $S$ , see fig. 6).



$\Delta C'_R$  AT THE SURFACE W. BEUKELSZ 28/2 - 4/3 1966

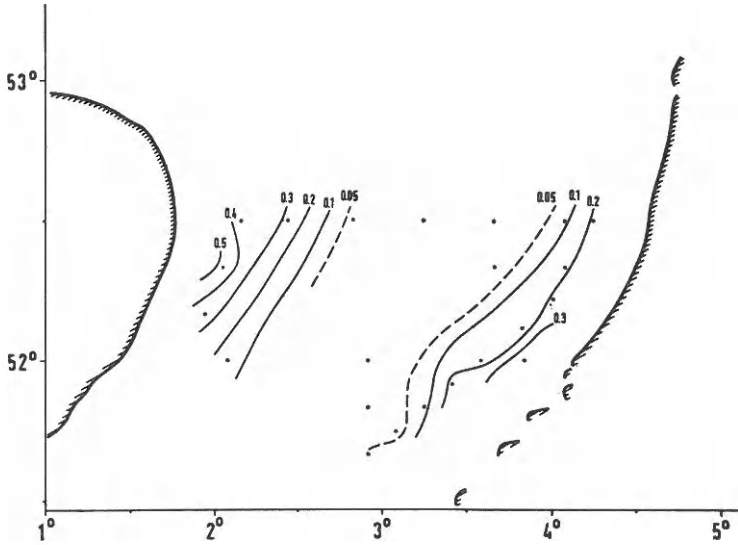


Fig. 5.  $\Delta C'_R$  at the surface of the Southern Bight of the North Sea, February 28 till March 4, 1966.  $\Delta C'_R$  in  $m^{-1}$

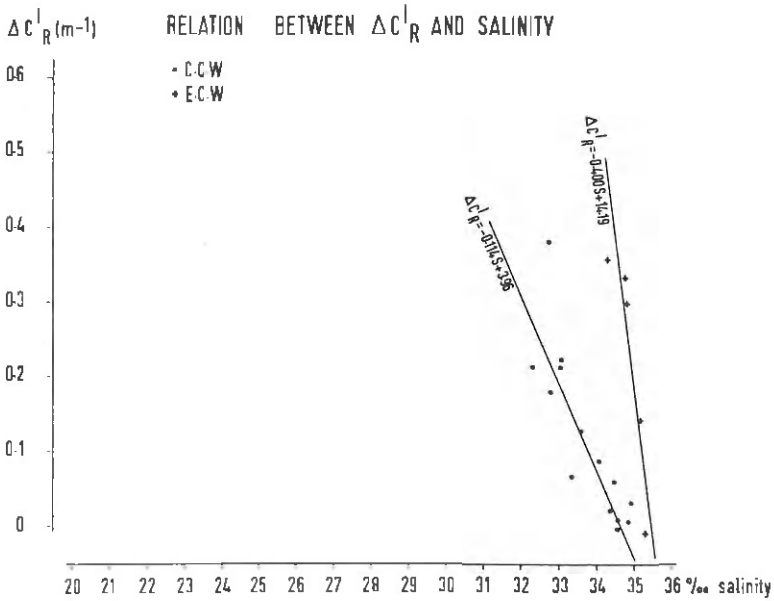


Fig. 6.  $\Delta C'_R$  - salinity relation. Points: Continental Coastal Water; crosses: English Coastal Water.

ECW:  $\Delta C'_R = -0.400 S + 14.19$  ( 6 observations, correl. coef. 0.84)

CCW:  $\Delta C'_R = -0.114 S + 3.96$  (15 observations, correl. coef. 0.90)

These two water masses can be considered as mixtures of three water types: Straits of Dover Water, English "fresh" water (mainly from the river Thames) and Continental "fresh" water (mainly from the river Rhine, but with some contributions by the rivers Meuse and Scheldt). These three water types are characterized by the following properties:

Straits of Dover Water:	$S = 35.7 \text{ ‰}$
	$F = 0$
	$\Delta C'_R = -0.1 \text{ m}^{-1}$
English fresh water:	$S = 0$
	$F = 122 \text{ mFl}$
	$\Delta C'_R = 14.2 \text{ m}^{-1}$
Continental fresh water:	$S = 0$
	$F = 75 \text{ mFl}$
	$\Delta C'_R = 4.0 \text{ m}^{-1}$

The values of  $\Delta C'_R$  and  $F$  for both "fresh" water types cannot be regarded as constant and may vary with the river discharge. Furthermore, they are in fact, extrapolations, which means that the effect of variations occurring as a consequence of biological or chemical processes during the initial mixing of fresh and sea water has not been considered. Nevertheless, the good linear correlations that have been found for the salinity range from 22 ‰ to 35 ‰ demonstrate that for a time interval of a week or so the above properties may be considered as useful indicators.

Finally we may consider the distribution of the attenuation coefficient for red light,  $C'_R$ , at the surface. This is shown in figure 7. Here the same pattern is seen as in the other figures. It appears, therefore, that this property is more or less related to the salinity, which could mean that the light attenuation is mainly caused by suspensions that behave as a dissolved substance. This assumption has to be further investigated. Therefore we here discuss the relation between light attenuation and the concentration of suspended matter, as determined at the Netherlands Institute for Sea Research for a number of surface samples taken during the cruise. The determination was made by a filtering and weighing method. Such a relation gives an indication of the size of the particles in suspension. We may derive an "effective optical diameter", defined as the diameter of a uniform suspension of quartz spheres that gives, for the same concentration (in mg/litre), the same attenuation as the suspension investigated (OTTO, 1966). For the computation of this "effective optical diameter" we use the light-scattering diagram of BURT (1956).

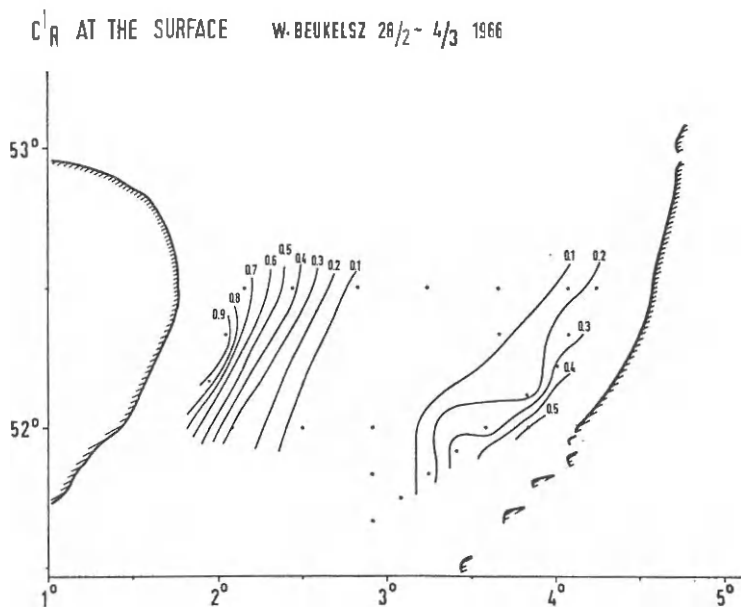


Fig. 7.  $C'_R$  at the surface of the Southern Bight of the North Sea, February 28 till March 4, 1966.  $C'_R$  in  $m^{-1}$ .

Now it has to be remarked that the relationship between the attenuation and the concentration of suspended matter for a certain water mass, given by JOSEPH (1953) only gives an estimate of the effective optical diameter of the particles in suspension for one of the two water types that compose the water mass in question, because the other water type (here called the Straits of Dover Water) has a negligible concentration of suspended matter.

The observations made at the stations that were situated in the English Coastal Water showed a reasonable linear correlation between the attenuation coefficient  $C'_R$  and the concentration of suspended matter  $G$

$$C'_R = 0.089 G - 0.06$$

( $C'_R$  in  $m^{-1}$ ,  $G$  in  $mg/l$ ) (6 observations, correl. coef. = 0.86).

The relation given by Joseph for his observations made in February and March 1952 in the same water mass, is

$$C'_R = 0.16 G + 0.09$$

Disregarding the difference in the constant term (which depends on the

definition of  $C'_R$  as a relative value), we see that the coefficient of  $G$  (the "specific attenuation" or "Spezifische Extinktion" as it is called by Joseph), differs by a factor of about 2. It is interesting to compare our result also with a previously obtained relation at an anchor station at  $52^{\circ}30'N., 02^{\circ}40'E.$  (a position that apparently lies in the English Coastal Water), made in March 1964.

$$C'_R = 0.036 G + 0.19$$

Thus we find for the same water mass, on different occasions with methods that are either exactly the same or that are at least comparable (Joseph's observations), values of the specific attenuation of 0.16, 0.089 and 0.036, giving effective optical diameters of about 3, 6 and 14  $\mu$ , respectively.

For the Continental Coastal Water, a significant relation between  $C'_R$  and  $G$  could not be found. Apparently in this case the effective particle size is not uniform throughout the whole watermass.

Nevertheless, in spite of the partly inconclusive results of the study of  $C'_R - G$  relations, the use of light attenuation as a water mass indicator should not be rejected completely. It has to be remarked that for both water masses reasonable correlations are found between the attenuation coefficient and the salinity ( $C'_R$  over  $S$ ):

$$\text{E.C.W. } C'_R = -0.762 S + 27.0 \quad (6 \text{ observations, correl. coef. } 0.84)$$

$$\text{C.C.W. } C'_R = -0.143 S + 5.0 \quad (15 \text{ observations, correl. coef. } 0.85)$$

The supposition is therefore made that there are two fractions of suspended matter, fraction I consisting of "permanently" suspended fine grained material, fraction II of coarser material, only temporarily in suspension.

An attempt will be made here to discriminate between these two fractions and the light attenuation caused by them along the following lines:

For fraction I perfect linear relationships were assumed to exist between  $S$  and  $C'_R$  on the one hand and between  $S$  and  $G$  on the other hand (see figs. 8 and 9).

The point taken to represent the Straits of Dover water type in the  $S - C'_R$  diagram is  $S = 35.7 \text{ ‰}$ ,  $C'_R = -0.15 \text{ m}^{-1}$ . (The value of  $C'_R$  is an average following from the substitution of  $S = 35.7$  in both  $S - C'_R$  relations, which gives  $C'_R = -0.2$  and  $C'_R = -0.1$  for E.C.W. and C.C.W., respectively). The value of  $G$  for this water type is assumed to be zero. The points representing the properties of the Straits of Dover Water must lie on the lines for the  $S - C'_R$  and  $S - G$  relations of fraction I.

Furthermore all the points for one of the two water masses, derived from actual measurements must lie either on the line for that water mass

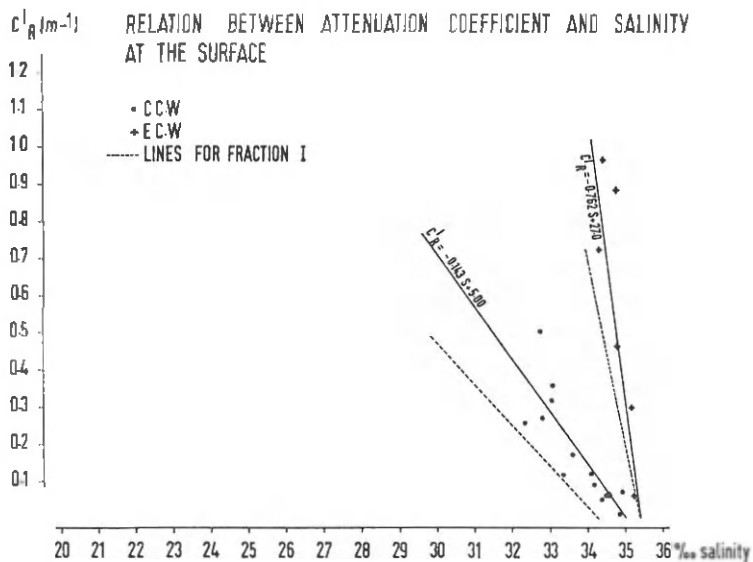


Fig. 8  $C'_R$  - salinity relation. Points: Continental Coastal Water; crosses: English Coastal Water.

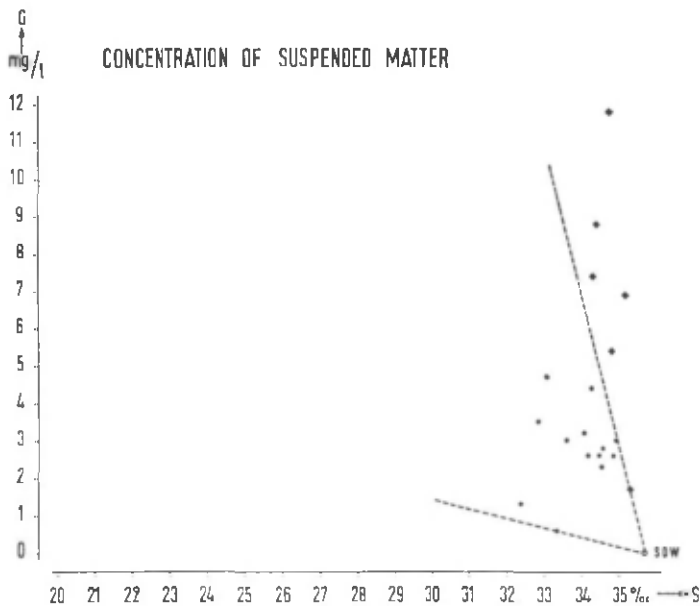


Fig. 9. Concentration of suspended matter versus salinity relation. Points: Continental Coastal Water; crosses: English Coastal Water.

or above it, since this line represents the limit, attained when fraction II of the suspension is zero. This line therefore has been drawn in the  $S-C'_R$  diagram through the point representing Straits of Dover Water and that one of the observational points that gives the smallest slope to the line.

This procedure can also be followed for the  $S-G$  diagram. Fraction II can now be estimated by comparing the values of  $C'_R$  and  $G$  found from the linear relationship for the observed values of  $S$  (fraction I) and the actual, measured values (fractions I and II).

The following relations were found for both fractions between the values of  $C'_R$  and  $G$  thus derived.

#### Fraction I

$$\text{E.C.W. } C'_{RI} = 0.12 G_I - 0.15 \text{ (follows from supposition)}$$

$$\text{C.C.W. } C'_{RI} = 0.42 G_{II} - 0.13 \text{ (follows from supposition)}$$

#### Fraction II

$$\text{E.C.W. } C'_{RII} = 0.06 G_{II} + 0.10 \text{ ( 6 observations, correl. coef. 0.83)}$$

$$\text{C.C.W. } C'_{RII} = 0.03 G_{II} - 0.02 \text{ (13 observations, correl. coef. 0.71)}$$

Of course, the results of the procedure described above are much dependent on the assumed values of  $S$ ,  $C'_R$  and  $G$  of the Straits of Dover Water, and therefore are by no means to be regarded as firmly established. However, two points should receive attention. In the first place the "specific attenuation" of E.C.W. for fraction I is much closer to the value 0.16 of Joseph. In the second place the fairly good correlation found for fraction II of C.C.W. indicates that the procedure followed is at least worth being attempted.

The effective optical diameters that can be derived from these relations are:

$$\text{E.C.W. fraction I} = 4.5 \mu$$

$$\text{,, II} = 9 \mu$$

$$\text{C.C.W. fraction I} = 1.5 \mu$$

$$\text{,, II} = 17 \mu$$

#### 4. SOME RESULTS OF THE OBSERVATIONS IN 1967

From January 30 to February 3, 1967, another cruise was made with "Willem Beukelsz" with the intention to study optical indicators.

This time only the eastern part of the Southern Bight was examined (no observations were made in the English Coastal Water). More

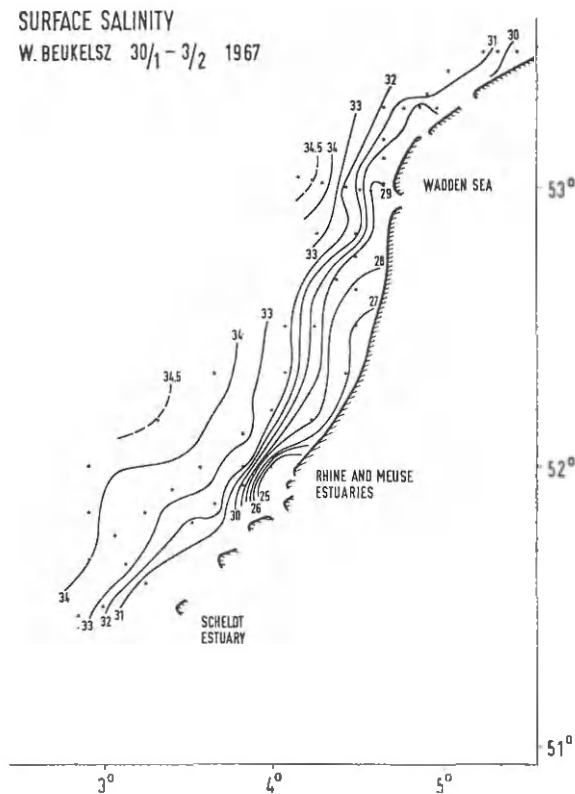


Fig. 10. Surface salinity of the waters along the Netherlands Coast. January 30 till February 3, 1967.

attention was now given to the difference between the water masses that are the result of mixing of sea water with fresh water originating from different (continental) sources. Observations of salinity and fluorescence could be made during the whole cruise, but attenuation measurements had to be restricted to the northern part of the area, because of adverse weather conditions during part of the voyage. Charts of surface salinity, fluorescence and  $\Delta C'_R$  charts are given in figures 10, 11 and 12.

It was attempted to use the salinity-fluorescence diagrams for making a separation between different water masses. The stations in the southern part of the region investigated, near the entrance of the Scheldt estuary, appeared to have a different fluorescence-salinity relations compared with those in the central and northern parts. It was assumed that this

## NATURAL FLUORESCENCE AT THE SURFACE

W. BEUKELSZ 30/1 - 3/2 1967

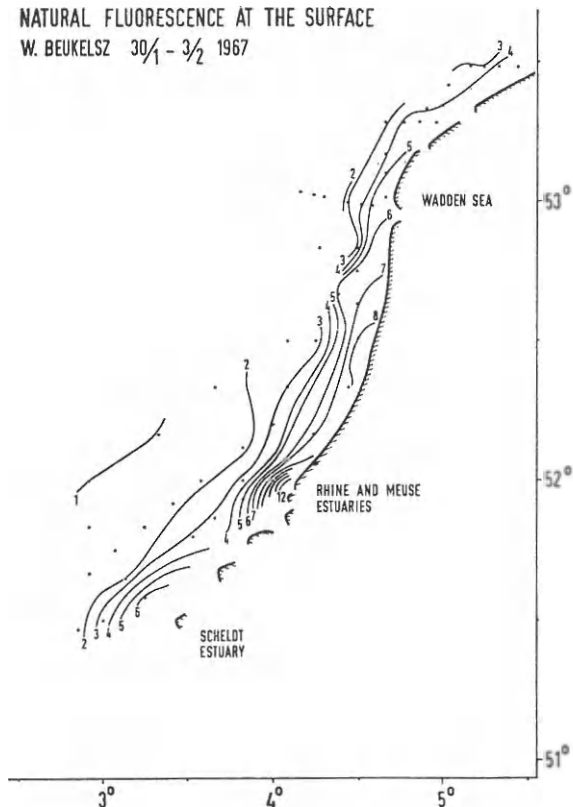


Fig. 11. Natural fluorescence at the surface of the waters along the Netherlands Coast, January 30 till February 4, 1967. 1 fluorescence unit = 2.1 mFl.

indicated the presence of two water masses, the first one being mainly a mixture of Scheldt water and "Straits of Dover Water", the second one originating from the mixing of Rhine and Meuse water with "Straits of Dover Water". Each of these water masses was thought to give a linear relation between fluorescence and salinity.

In this situation we may expect that there will be a transition area in which these two water masses mix. Observations made in water consisting of such a mixture will give points in the salinity-fluorescence diagram that are situated between the two lines representing both "pure" water masses. In order to find these lines, we have to select those observations, that are thought to approximate the "pure" water masses. This selection



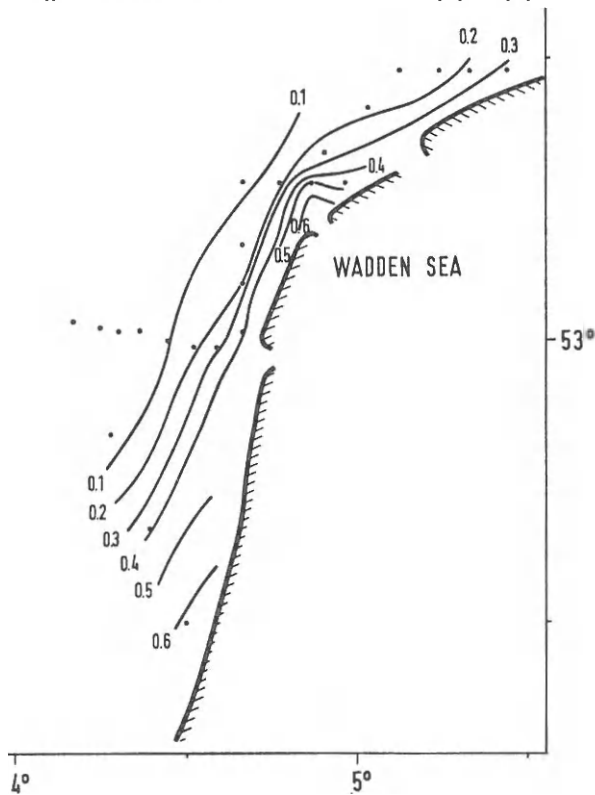
$\Delta C'_R$  AT THE SURFACE W. BEUKELSZ 30/1 - 31/1 1967

Fig. 12.  $\Delta C'_R$  at the surface of the waters along the Netherlands Coast, January 30 and 31, 1967.  $\Delta C'_R$  in  $m^{-1}$ .

was based on the observed values of salinity and fluorescence and on the presumed general distribution of the water masses in question. Therefore the definition of the water masses is not completely free from subjectivity, but the overall picture that finally is obtained gives confidence in the procedure followed.

The observations used for the definition of the "Scheldt water mass" are situated in a section perpendicular to the shore, starting from the entrance of the estuary. The observations used to define the "Rhine-Meuse water mass" were made on a section parallel to the coast, from the Hook of Holland north-eastwards.

The relations found are (fluorescence  $F$  in mFl over salinity, see fig. 13):

## RELATION BETWEEN FLUORESCENCE AND SALINITY

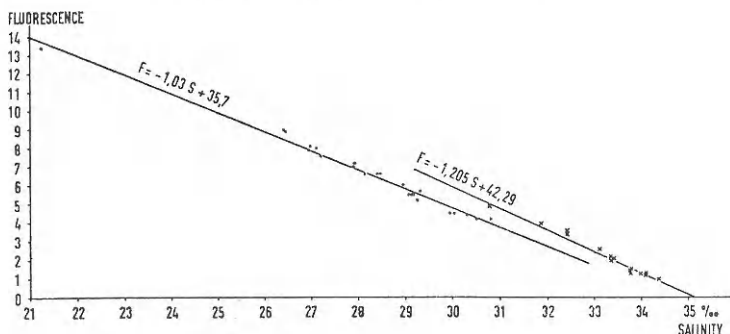


Fig. 13. Fluorescence-salinity relation. Points: Rhine-Meuse water mass; crosses: Scheldt water mass. 1 fluorescence unit = 2.1 mFl.

“Rhine-Meuse water mass”:  $F = -2.16S + 75.0$  (24 observations, correl. coef. 0.98)

“Scheldt water mass”:  $F = -2.53S + 88.8$  (23 observations, correl. coef. 0.99)

No attenuation measurements were made in the “Scheldt water mass”, and therefore it is not possible to tell whether a similar distinction between watermasses could also be made on the basis of  $\Delta C'_R$  values. For the “Rhine-Meuse water mass” the following relation was found (regression of  $\Delta C'_R$  over  $S$ , see fig. 14):

$$\Delta C'_R = -0.105 S + 3.39 \text{ (10 observations, correl. coef. 0.96)}$$

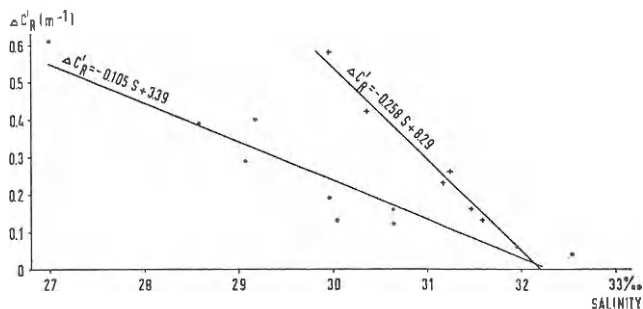
RELATION BETWEEN  $\Delta C'_R$  AND SALINITY

Fig. 14.  $\Delta C'_R$  - salinity relation. Points: Rhine-Meuse water mass; crosses: Wadden Sea water mass.

It appeared that in the northern part of the area investigated a group of observations had a different  $\Delta C'_R$ - $S$  relationship, with much higher  $\Delta C'_R$  values, whereas the  $F$ - $S$  relationship did only show small deviations from the "Rhine-Meuse" values. The water in the northern part was characterized by ( $F$  and  $\Delta C'_R$  over  $S$  regression lines):

$$F = -1.98 S + 69.6 \text{ (11 observations, correl. coef. 0.98)}$$

$$\Delta C'_R = -0.258 S + 8.29 \text{ (6 observations, correl. coef. 0.99)}$$

It might be assumed that the high values of  $\Delta C'_R$  could be caused by selective absorption by sediment that has been temporarily stirred up by tidal currents in this shallow coastal area and even may influence the attenuation at the surface to a considerable degree. This would mean that the relation between  $\Delta C'_R$  and salinity found for these observations would not be characteristic for a water mass, but is more or less fortuitous. This assumption, however, becomes less probable if we consider the fact that the observations were made at different phases of the tide. It is thought, therefore, that these relations characterize a true water mass, which possibly originated from the Wadden Sea. It has therefore tentatively been called "Wadden Sea Water mass".

No samples of suspended matter were taken during this cruise. As, therefore, it is not possible to evaluate the relation between attenuation and concentration of suspended matter, we shall not discuss the use of the attenuation coefficient as an indicator and only remark that the  $C'_R$ - $S$  relation also favours the distinction between the "Wadden Sea Water mass" and the "Rhine-Meuse water mass".

Using the relations found for the different water masses, it now is possible to analyse the observations made in the mixing zones between these water masses.

The water consisting of a mixture of, for instance, the "Scheldt water mass" and the "Rhine-Meuse water mass" is characterized by the salinity  $S$  (determining the total fraction of "fresh" water in the mixture) and by the percentages of both contributing "fresh" water sources to the total quantity of "fresh" water. For each observation these percentages may be determined from the relations of the contributing water masses as given on page 548.

The percentage of "fresh" Scheldt water in a given mixture with salinity  $S$  and fluorescence  $F$  was thus computed from:

$$\frac{F-F_R}{F_S-F_R} \times 100 \%$$

$$\text{where } F_R = -2.16 S + 75.0 \text{ and } F_S = -2.53 S + 88.8$$

In this way the percentages of the fresh water, originating from either Scheldt or Rhine-Meuse can be found for the different observations. A similar procedure gives the percentages for the Rhine-Meuse and the fresh water fraction of the Wadden Sea Water. At the 50% boundaries between the watermasses equal proportions of both watermasses occur. These boundaries are shown in figure 15.

It is thought that such a discrimination between water masses originating from mixing with "fresh" water from different rivers may be useful in a further study of the circulation of water in the sea.

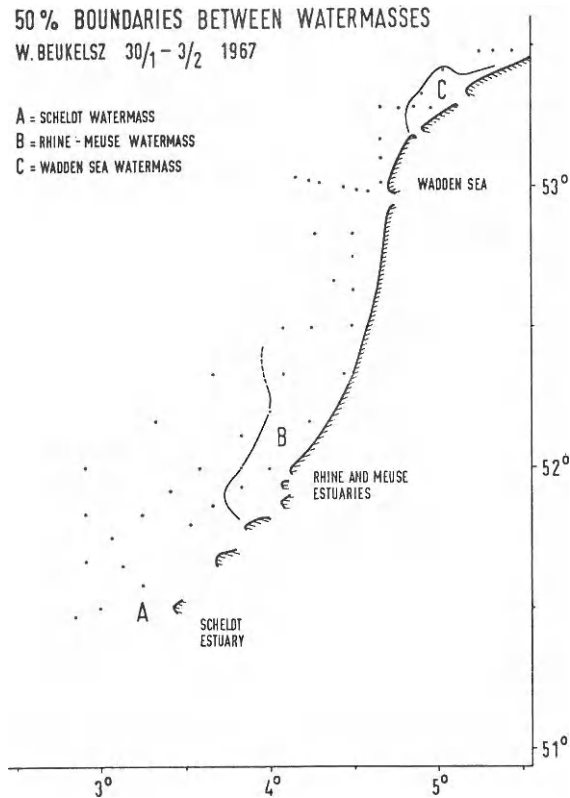


Fig. 15. Fifty per cent boundaries between different water masses along the Netherlands Coast, January 30 till February 3, 1967.

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## SUMMARY

The use of some optical properties for the characterization of water masses in the Southern North Sea is discussed. These properties are the natural fluorescence of sea water, and the attenuation coefficient of red light, as well as the difference between the attenuation coefficients of blue and of red light (as a measure of "Gelbstoff" content). Observations, made in the winters of 1966 and 1967 are investigated and discussed. It appears possible to discriminate between English Coastal Water and Continental Coastal Water, but also to subdivide the Continental Coastal Water into watermasses in which the influence of different fresh water sources is predominant.

The relation between light attenuation and concentration of suspended matter is discussed.

The "effective optical diameter" of the particles in suspension appears to vary at different occasions.

A method is indicated by which it may be possible to make a distinction between coarser and finer fractions in the suspension.

## NOTE ADDED IN PROOF

The use of the light attenuation as an indicator for water masses has been discussed by A. J. LEE and A. R. FOLKARD in a paper presented to the Hydrography Committee during the 55<sup>th</sup> meeting of the International Council for the Exploration of the Sea, held in Hamburg, October 1967 (CM 1967/C:25). It was shown that there is a discrepancy between the salinity and turbidity distributions in the western part of the Southern North Sea, the area of minimum salinity not coinciding with the area of maximum turbidity. Also time variations in turbidity occurred that are ascribed to sediment, stirred-up by wave action.

Observations of the particle size distribution of the suspended matter in the range 6-24  $\mu$  were made with a Coulter Counter. It appeared that in the water mass studied the suspension was fairly uniform throughout the whole turbidity range.

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