Ministry of Transport, Public Works and Water Management

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Atlas of near-surface Total Suspended Matter concentrations in the Dutch coastal zone of the North Sea

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Preface

Suspended matter in the water column governs the under water light climate and is thus an important factor for life in the sea. Next to nutrients, light is essential for the growth of phytoplankton and in this way for the food chain in the sea. Suspended matter concentrations are highly variable in time and space. Thus it is very hard to assess the influence on these concentration levels of any anthropogenic acting. Furthermore, the relations between suspended matter and the food chain are very complicated. These two facts hamper a fair estimate of the effects on the ecosystem of foreseeable anthropogenic measures that may infer changes in suspended matter transports. As a prerequisite for managing a sustainable use of the North Sea, basic information on the highly variable suspended matter concentrations in the marine environment is therefore needed.

Through charts and graphs, this atlas gives an insight in the near-surface suspended matter concentrations and their variability in the Dutch coastal zone (ca. 70 km wide). The charts of the near-surface suspended matter concentrations are based on the DONAR[1] data of the monitoring WAKWON programme[2] carried out between 1975 and 1983. The variability in space and time is further elucidated by dedicated graphs and charts.

As a result of research (Suijlen and Duin, 2001) the suspended matter concentrations appear to be mainly determined by the wave heights. This results in high concentrations during the stormy winter periods and low concentrations during calm summer periods. Besides a seasonal variability, a long-term variability exists with periods of 4-8 years.

Taking into account the variability in the concentration levels, it is estimated that the nett northward transport of suspended matter in the coastal zone (ca. 70 km wide) ranges between about 6 and 60 Mton per year. This transport depends on the waves during that year, as well as on the flux of sediments from the English Channel and the Flemish banks.

Although based on data measured between 1975 and 1983, the charts and graphs presented in this atlas are representative for the present suspended matter concentrations (chapter 5.2 of Suijlen and Duin, 2001).

The production of this atlas was commissioned by the North Sea Directorate (NSD) of the Directorate-General of Public Works and Water Management. The project manager at NSD was drs. A. Stolk.

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[1] DONAR is the database of Rijkswaterstaat which contains among other things environmental data

[2] After 1983 the number of stations was strongly reduced and optimised for the monitoring programme MWTL

Introduction

The total suspended matter concentration (TSM) plays an important role in the marine system of the North Sea. TSM is the main source of turbidity, which determines to a large extent the underwater light climate. Under water light and nutrients are the determining factors for primary production, which is the basis of the food chain in the sea. Marine suspended sediments in the Dutch coastal zone originate mainly from the English Channel and the Flemish Banks. Because of the large flux (order of 20 Mton/year) in a relatively narrow band along the coast (<10 km), the flow of marine suspended matter also strongly affects the navigational depth of the channels to the Dutch sea ports, causing the need for substantial maintenance dredging.

The natural variability of TSM values is known to be large. Anthropogenic influences on the TSM will therefore be relatively difficult to detect. Examples of human activities potentially affecting the turbidity in the water column are sand mining and dredging of shipping lanes. For a sustainable use of the North Sea the responsible authorities need adequate information about the natural system and on possible effects from its use.

This atlas provides information on the statistics of the natural near-surface total suspended matter concentrations (TSM). Such information is needed for testing hypotheses about foreseeable changes in the turbidity levels originating from potential human activities. The information is condensed mainly in charts and graphs.

The first charts deal with some physical properties of the area investigated (Charts 1-4, bathymetry, mean salinity, mean river water percentage and mean TSM). The mean values of the TSM during more closely specified summer and winter periods are shown in Charts 5 - 8. Besides these basic charts typical TSM distributions after calm and stormy weather are shown in the Charts 9 -12. The interpolation between the mean values of the individual stations is based on triangulation (Suijlen and Duin, 2001).

The graphs deal mainly with details of the cross-shore dependency of the TSM. Graph 1 shows the TSM at four cross-shore transects. Graphs 2 and 3 show summarising graphs, where the mean, median and mode are given in virtual cross-shore transects South (Graph 2) and North (Graph 3), which are based on aggregation of transects south and north of Hook of Holland, respectively. Graph 4 demonstrates that TSM-signals have long-term variations.

All charts and most graphs are based on DONAR data obtained in the WAKWON programme between May 1975 until March 1983 (Rijkswaterstaat and WL-Delft, 1985). Only the data of this period are suited for a presentation by contour lines in charts. The Graphs 1.4 and 4 are based on DONAR data collected between 1975 and 1999. These DONAR data are the combined results of the large WAKWON monitoring programme of the Dutch Coastal zone by Rijkswaterstaat and the current MWTL long-term monitoring programme (Rijkswaterstaat, 1992). The survey frequency was about 22 and 13 times a year for the WAKWON and MWTL programme, respectively. All stations were surveyed within about 4 days, resulting in quasi-synoptic surveys.

Two tables present numerical values of some statistical parameters which are the basis of the mentioned Charts and Graphs.

The research for this atlas is reported elsewhere (Suijlen and Duin, 2001) where details about the methods can be found.

Area investigated and yearly mean near-surface total suspended matter concentrations

Chart 1 shows an overview of the bathymetry and the monitored stations. The monitoring stations are located in ten profiles perpendicular to the coast. Each profile consists of 6-9 stations at regular distances to the coast (mostly 1, 2, 4, 10, 20, 30, 50 and 70 km). The stations are indicated by a character that identifies the profile, and a figure that gives the distance to the coast (e.g. N10 in the N-profile).

The distributions of the yearly mean values of the salinity and of the fresh water content are shown in Charts[3] 2 and 3 respectively (salinity of pure sea water and pure river water is chosen equal to 35.1 and 0.4, respectively). Chart 4 presents the yearly mean TSM[4] distribution. The data of the yearly means are contained in table 1 of Suijlen and Duin (2001).

The positions of the contour lines of the fresh water percentages are determined by the residual flows in the Southern part of the North Sea and by the fresh water originating from the rivers. The influence of the most important fresh water sources (e.g. the Rhine-Meuse near Hook of Holland) is clearly visible. The bending of the fresh water plumes to the northeast along the Dutch coast demonstrates that the residual (surface) currents are in a northeasterly direction parallel to the coast. The TSM contour lines in Chart 4 show also a north-eastern directed pattern along the Dutch coast with the highest TSM concentrations near the A and W-transects. The total suspended matter in the Dutch coastal zone originates mainly from the English Channel (Van Alphen, 1990) and is carried along the Dutch coastal zone by the (tidal) currents. On-shore directed near-bottom residual currents (Van der Giessen *et al.*, 1990), originating from density differences between river and sea water near the outflow of the Rhine, concentrate the suspended matter in a relatively narrow band (Van Alphen, 1990), resulting in the large observed gradient (cf. Chart 4 and Graph 1). Furthermore, the observed high concentration values in the shallow near-shore zone are caused by wave action.

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[3] the numbers along the axis of the charts are UTM coordinates (km)

[4] All matter which remains on a 0.45 µm cellulose acetate filter

Charts of the seasonal mean of the near-surface total suspended matter concentrations

A statistical analysis has demonstrated that the available data can't provide meaningful estimates, per station and per month of the year, of statistical parameters like the mean, median and standard deviation of the TSM: the TSM values scatter too much and the number of available data is relatively small (e.g. in total 12 and 8 data of the months November and December, respectively). Some aggregation of data is therefore necessary, e.g. by considering longer periods (more than one month) for which statistical parameters are estimated. It was made plausible elsewhere (Suijlen and Duin, 2001) that waves have a great effect on the resuspension processes in the shallow water in the Dutch coastal zone. Therefore we cluster the measured TSM data in two subsets that correspond with the two seasons of the wave climate. Monthly averaged wave heights show a typical seasonal trend with minimal heights during the summer months from May to October, while the largest wave heights, and TSM values, are found in the months from December through March (Suijlen and Duin, 2001). The lowest TSM concentrations are found in May through October or November depending on the region. In this atlas all charts and graphs are based on analyses with as Winter period the interval 1 December - 31 March and as Summer period 1 May - 31 October. The numerical results of the statistical analyses for these periods are summarised in table 1 for each station.

Estimates of the means of the TSM values, both for the summer and winter period, are plotted (contours) in Charts 5 and 6, respectively. The Charts 7 and 8 show the mean TSM contours in the coastal zone between Hook of Holland and Texel. The underlying data are contained in table 1. The several statistical quantities (mean, median, mode) are contained in this table since each of them gives different information about the TSM values with their asymmetrical distributions (cf. Appendix).

In all charts the highest values are found near the coast. Some of the charts suggest detailed structures in the contour lines that mainly are artefacts due to the interpolation technique (Suijlen and Duin, 2001). A notable exception is the TSM minimum (< 4 mg/l) across the N and E-transects during the winter (Charts 6 and 8) that has a physical basis. It is caused by density currents which are stronger during the winter than during the summer (Van der Giessen *et al.*, 1990).

The mean ratio between the mean and mode of the TSM distribution appears to be about 2 (winter) or 3 (summer), while that between the mean and median is about 1.2 (both winter and summer). It has to be kept in mind that the standard deviation of the mean is nearly equal to the mean (coefficient of variation is between about 0.5 and 1.5). This means that an individual (quasi)-synoptic survey can deliver TSM results that differ strongly from the mean TSM distributions shown in the Charts 5 - 8.

Charts of extreme values of near-surface total suspended matter concentrations

The response of the TSM to storms is illustrated in Chart 9 which gives the mean concentrations of four surveys that are representative for periods after stormy weather with wave heights HTE3 larger than about 1.2 m. The parameter HTE3 is a measure for the wave height of waves with periods between 10 and 30 s (Rijkswaterstaat, 1992), which can penetrate the water column till the bottom. These waves are important for the suspension of sediments from the bottom. The four surveys, starting on 5 April 1977, 7 January 1981, 9 February 1981 and 23 February 1981, respectively, are aggregated in this chart to obtain a smooth distribution that is considered to represent stormy conditions. The mean values of the concentrations per station show values of 10-15 mg/l in the open sea for depths larger than 20 m. These values are about a factor 3-4 times higher than the mean values for the whole winter periods (cf. Chart 6) . During the storms themselves the actual TSM values have probably been larger. These higher values could not be actually measured since surveys are made only during the less stormy periods with wind forces smaller than about 8 Bft.

Chart 10 shows a synthetic TSM distribution. It was obtained by interpolating the TSM values per station that are the mean of the two highest values observed at each station. In this procedure, for the various stations different surveys have been used. The main purpose of Chart 10 is to illustrate that the actual maximum values during storms will be higher than the values in Chart 9, i.e. the TSM values during storms (Bft> 8) will in general be higher than those in Charts 9 or 10. The TSM values in the open sea range from 20 to 30 mg/l for the synthetic distribution of Chart 10, which is about a factor two higher than the values in Chart 9, and about a factor 8-10 higher than the yearly mean values (cf. Chart 4).

Surveys with lowest TSM values are found during the summer period. Chart 11 shows the contours of the mean values of the summer surveys of 28 July 1978, 13 July 1981, 7 September 1981, and 17 May 1982. The concentrations in the open sea are as low as 1 mg/l. An interpolated Chart (not shown) derived from the 2 lowest measured values per station (synthetic map analogous to the above one for the 2 highest values) does not contain much information, since all values equal the detection limit (= 0.1 mg/l), except for some stations in the first kilometres (< 2km) from the coast.

Chart 12 shows the interpolated mean TSM values of two surveys (survey 22 March 1977 and survey 22 January 1981) at relatively calm conditions in the storm season. The surveys were performed between surveys with high TSM values (i.e. 14 February and 5 April 1977, and 7 January and 9 February 1981, respectively, cf. table 8 Suijlen and Duin, 2001). In large parts of the open sea (seaward of the – 20 m contour) the values are as low as about 1-3 mg/l. Obviously, in that area the system responds quickly (within 1-2 weeks) to a decrease in wave energy. This can be seen by comparing Chart 9 (just after storms, i.e. 1-3 days after a storm) with Chart 12 (calm periods between storms).

Cross-shore graphs of near-surface total suspended matter concentrations

The seasonal means of the TSM values per station at the W, N, E and TS-transects are shown in Graph 1 (graphs 1.1-1.4, respectively) . These graphs are better suited to illustrate the large cross-shore gradients than Charts 5, 6, 7 and 8. The underlying data are contained in table 1.

As a further means to obtain better statistics, TSM data of the various measuring stations can be clustered into sub-regions of the coastal area. To this end the study area is divided into a southern and a northern region. The southern region contains the transects W, S and G (Chart 1) south of Hook of Holland. The northern region contains the transects T through TS. Justification of the selection of these areas was found in an inspection of the observed mean TSM values in the study area. The method of aggregation is based on the almost identical distances to the coast of corresponding stations. Details of the method are given elsewhere (Suijlen and Duin, 2001). For each clustering area a virtual aggregated transect South respectively North was derived. Table 2 presents the results of statistical analyses for the clustered stations. The cross-shore gradients of the TSM data in the South and North transects are illustrated in Graphs 2 and 3, respectively. The mean, median (cf. Appendix) and mode of the TSM are presented in the graphs. Presenting the mode and mean in a single graph highlights the difference between the two. To emphasize the differences between the near coast area (< 6 km) and the open sea (>15 km) the data of the 10 km stations are not used for the mean values mentioned in the boxes of graph 2 and 3. The boxes show the mean of the mean TSM values at the stations at 1, 2, 4, and 20, 30, 50, 70 km, respectively. The TSM data of stations at 10 km from the coast are intermediate between the TSM of the near coast part and the open sea. The occurrence of maximums at South2 and South4 (cf. Graph 2) is merely due to the contributions of W2 and W4 which are larger than that of W1 (cf. table 1).

Table 2 shows also the results with an alternative Winter period November through April (“Lwinter”). The means and medians of the Winter December through March are about 5-20% larger than those during the Lwinter (cf. table 2). This result is in accordance with the average wave climate during the Lwinter period being lower than during the winter December through March.

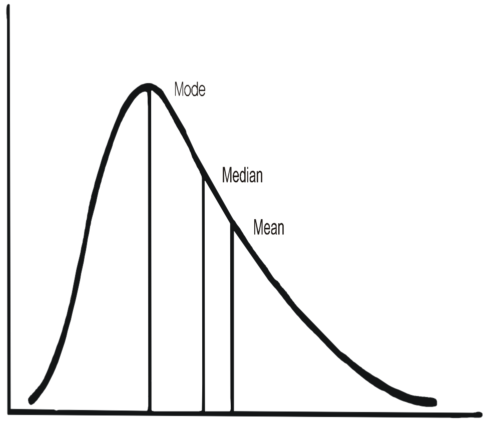
Long-term variability of near surface total suspended matter concentrations

Graph 4 presents moving averages of TSM values observed at the stations W20 and N20 in the W and N-transects, respectively; the data have been filtered by taking moving averages (time window 2 years; no weighting of the data) of 2-monthly average values. The used DONAR data are obtained during the WAKWON surveys frequency about 22 times per year) and the MWTL surveys (frequency about 13 times per year with minima of 9 surveys per year in 1990 and 1998). Since the moving average filter is only applicable on equidistant time series, while the surveys are not equidistant in time, we replace the original data by mean values for equidistant periods. Because of the frequency minima of 9 per year a 61 days period ('two months') is chosen for the averaging.

These moving averages show a periodicity of some 3-8 years. It is not impossible that the latter periodicity corresponds with the so-called North Atlantic Oscillation (NAO), which has a major periodicity of 7.3-8.0 year, as well as periodicities of 2.2 and 20 years (Rogers, 1984). The NAO is the large-scale alternation of the atmosphere between the Azores High and the Icelandic Low. The NAO is responsible for periods with heavy zonal storm tracks, transporting cyclones towards Western Europe, and for blocking phases with a reduced influence of the Atlantic on the weather in Europe.

In the above-mentioned long-term cycle (3-8 years) in the TSM moving averages, their values vary with a factor 2 (Graph 4). The moving averages of the salinities appear to have about the same periodicity. An increase c.q. decrease of the salinity at the station W20 implies an increase respectively decrease of the flow, or residual displacements, of oceanic water through the Strait of Dover. Of course the salinity at this station is also influenced by the flow rates of the rivers Rhine, Meuse and Scheldt, so salinity changes can partly be caused by changing river run-offs. According to Otto *et al*. (1990), the residual fluxes through the Dover Strait vary with about a factor 2-3. It appears that the moving averages of salinity and TSM are mainly out of phase before 1985 and mainly in phase after 1987. Therefore the residual TSM transport, which is a product of the long-shore flow and the suspended matter concentration, will vary with about a factor 2-6. So, for an estimated long-term TSM load of 20 Mton/year (Rijkswaterstaat-WL, 1985; Salden, 1998), the mean load in a specific year can be low (e.g. between 6-10 Mton/y) as well as high (e.g. 40-60 Mton/y).

Appendix: asymmetrical probability distribution



The (arithmetic) mean and median (the value such that there are equal numbers of larger and smaller measured values) are measures for the central part of a probability distribution. The mean is sensitive to the contributions of extremes in the distribution, while the median is nearly independent of the extreme values. The mode is the most frequently occurring value and is nearly independent of large values that may occur during episodic events (i.e. storms in the case of TSM). The mode of the TSM distribution is suited to obtain information about the under water light climate which biota experience during most of the time. The mean is more appropriate to information about suspended matter transports which can be very large during stormy weather.

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Mr. M. Geurtz carried out the quality checks on retrieving the data from the DONAR database. Mr. G. Poot produced the information about the bathymetry. Drs. A. Stolk is acknowledged for his critical reading of the manuscript. We would like to thank dr. R. Spanhoff for his profound discussions during the study and for his comments on the manuscript.

Charts

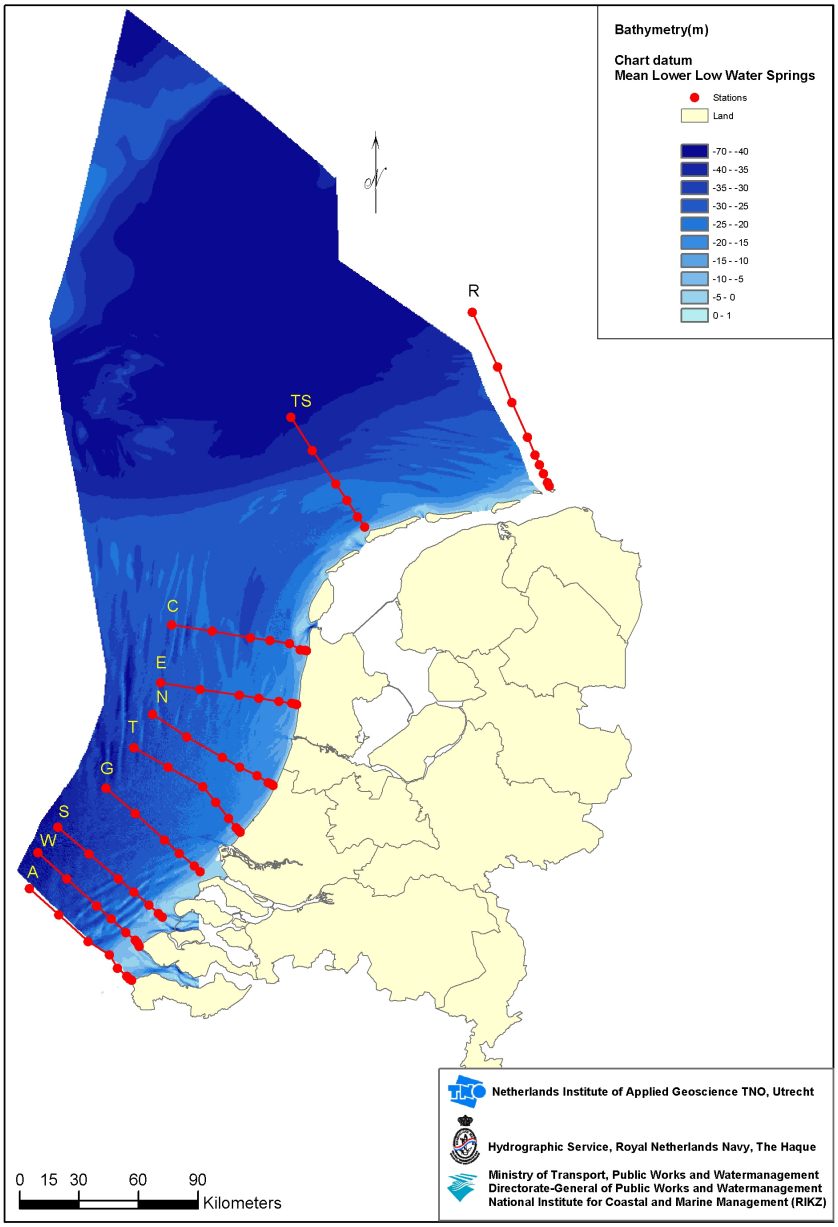


Chart 1 Bathymetry of the investigated area and the locations of the monitored stations

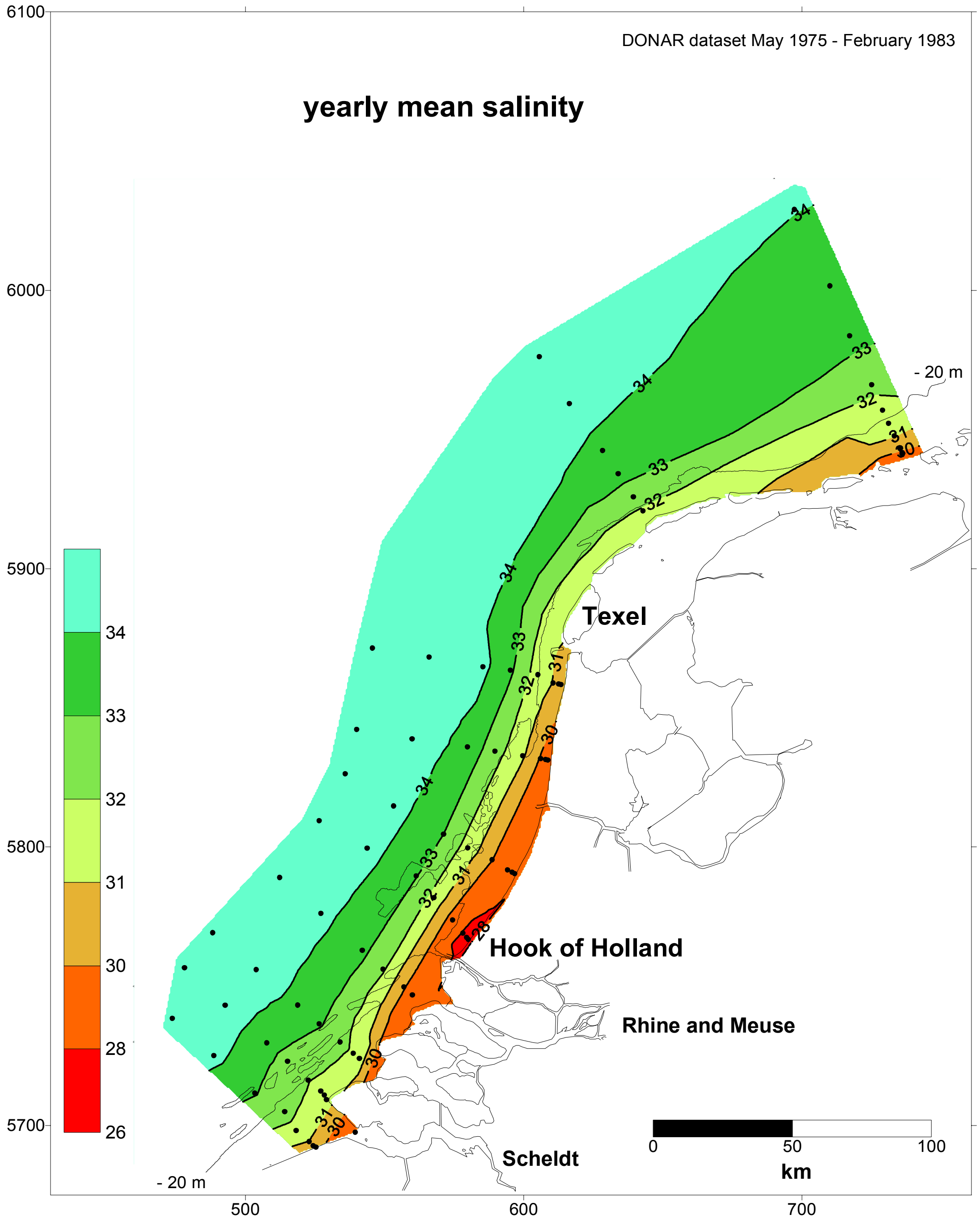


Chart 2 Yearly mean near-surface salinity in the Dutch coastal zone

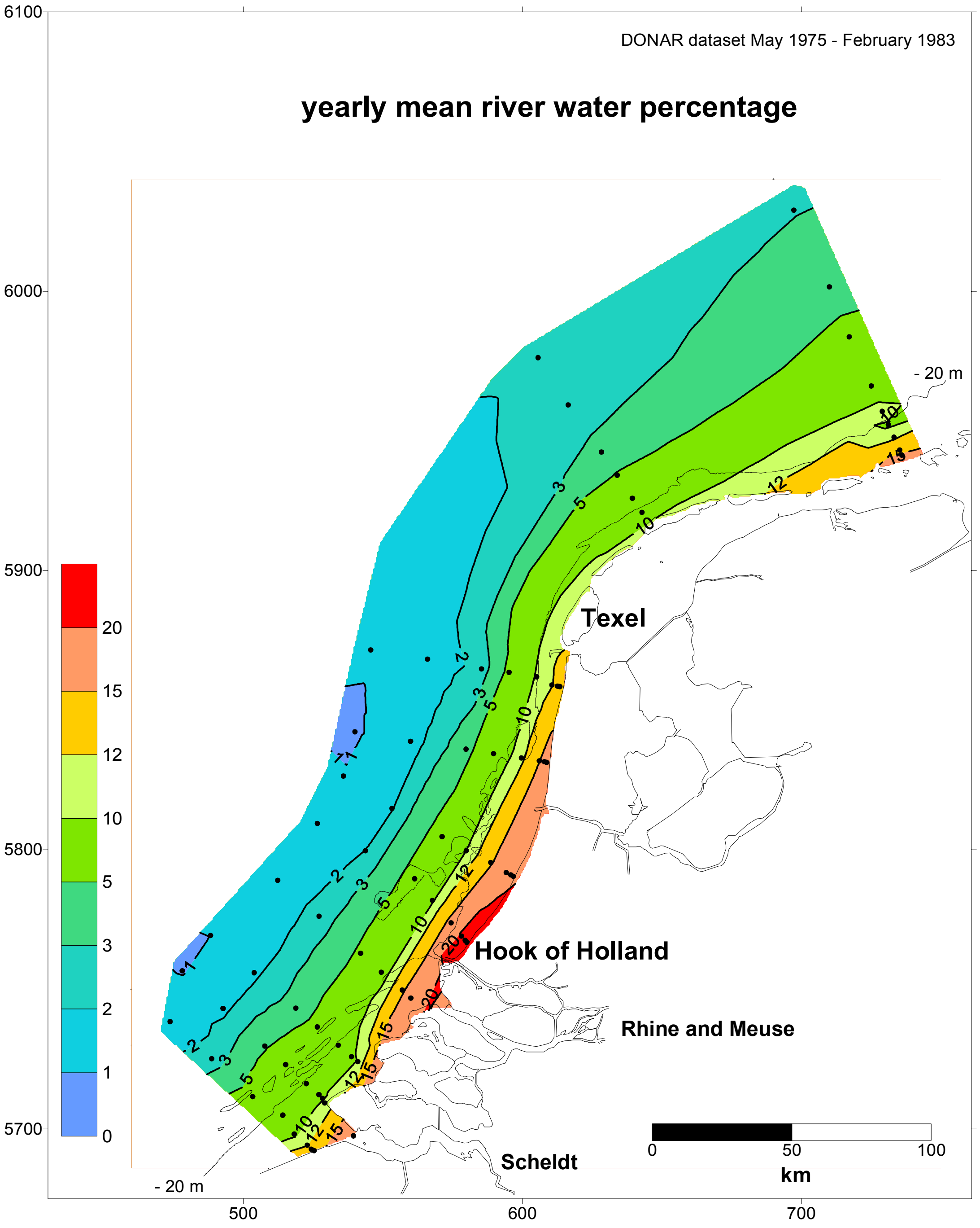


Chart 3 Yearly mean fresh water percentage in the Dutch coastal zone

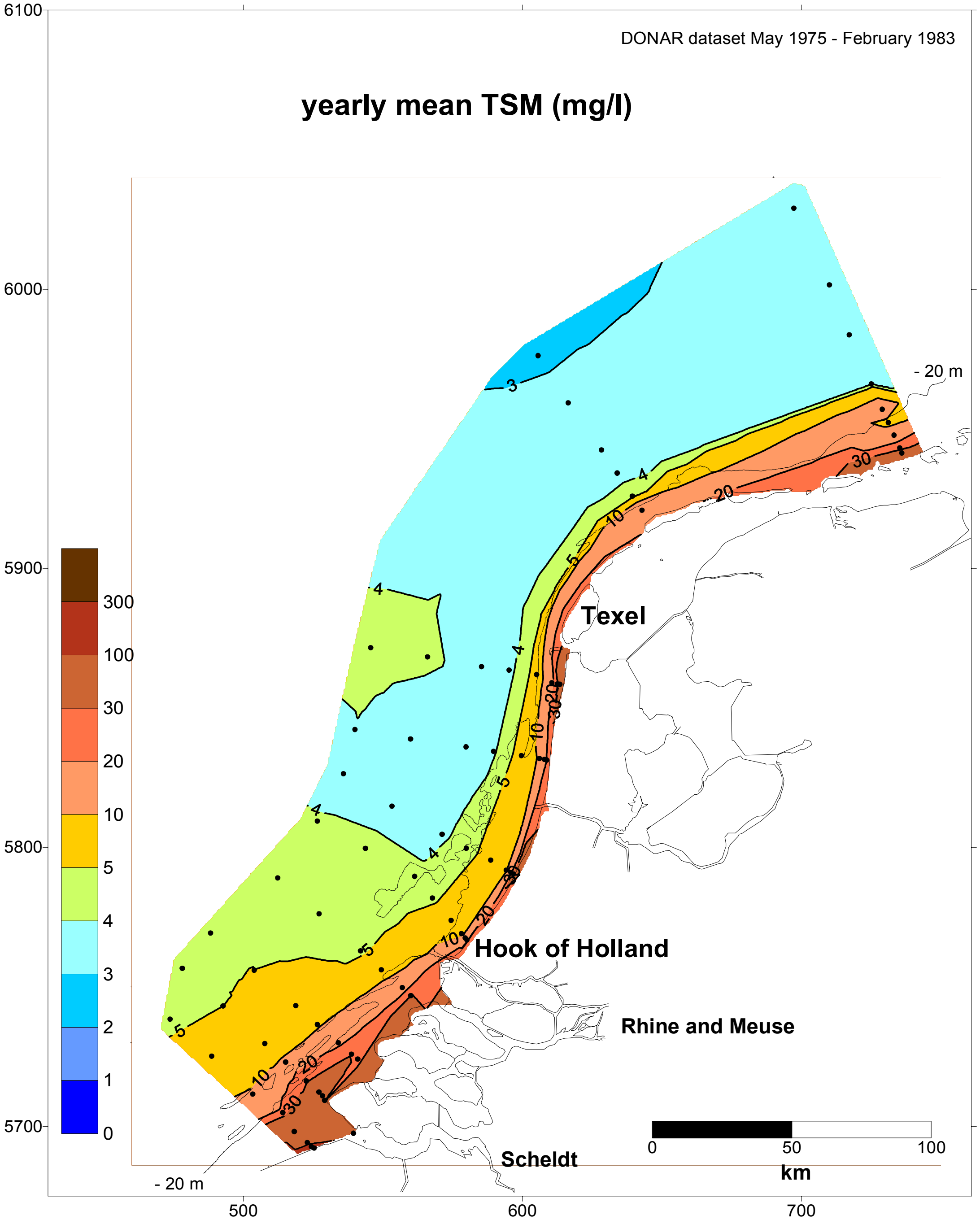


Chart 4 Yearly mean near-surface total suspended matter concentrations in the Dutch coastal zone

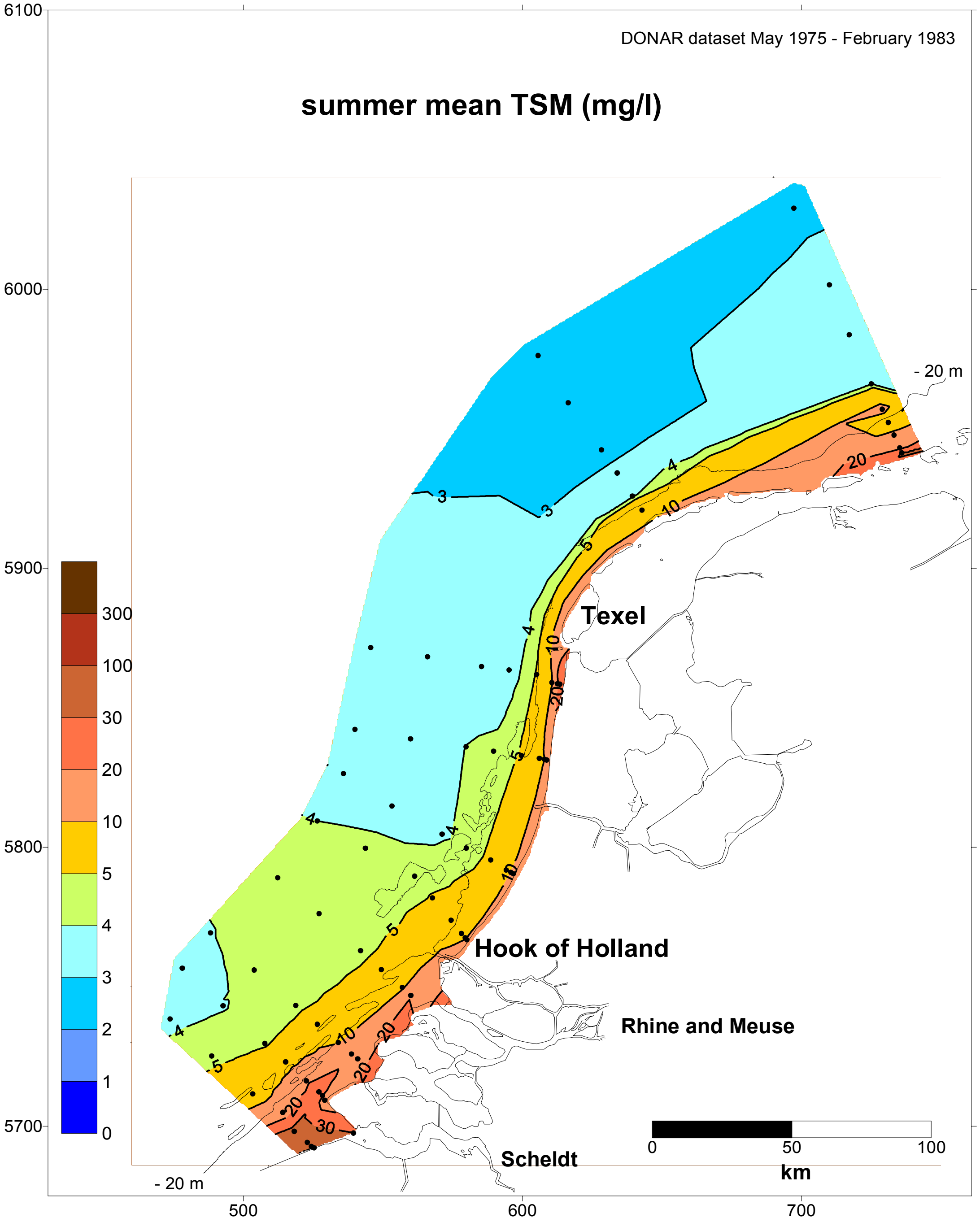


Chart 5 Summer means of near-surface total suspended matter concentrations (1 May – 31 October)

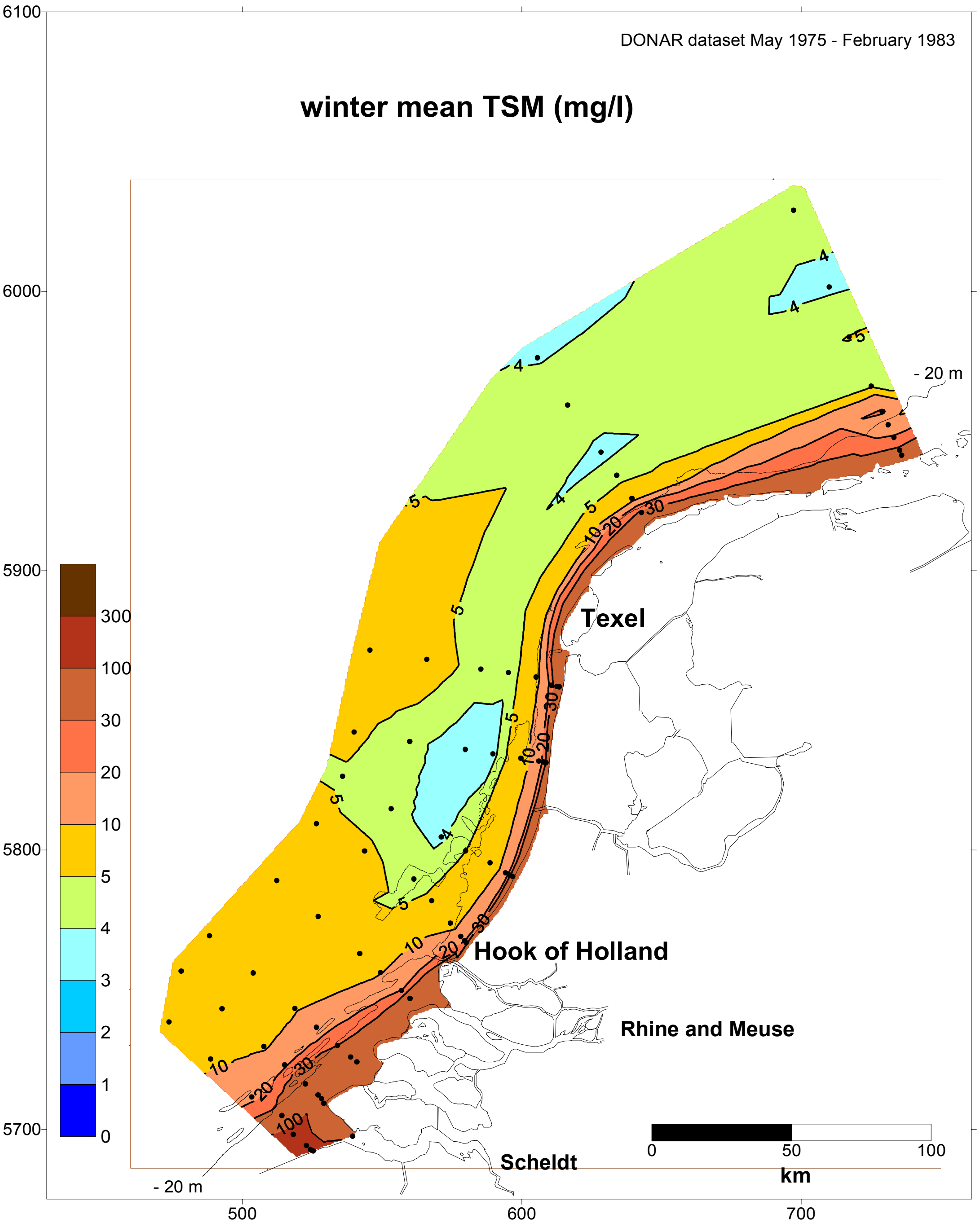


Chart 6 Winter means of near-surface total suspended matter concentrations (1 December – 31 March)

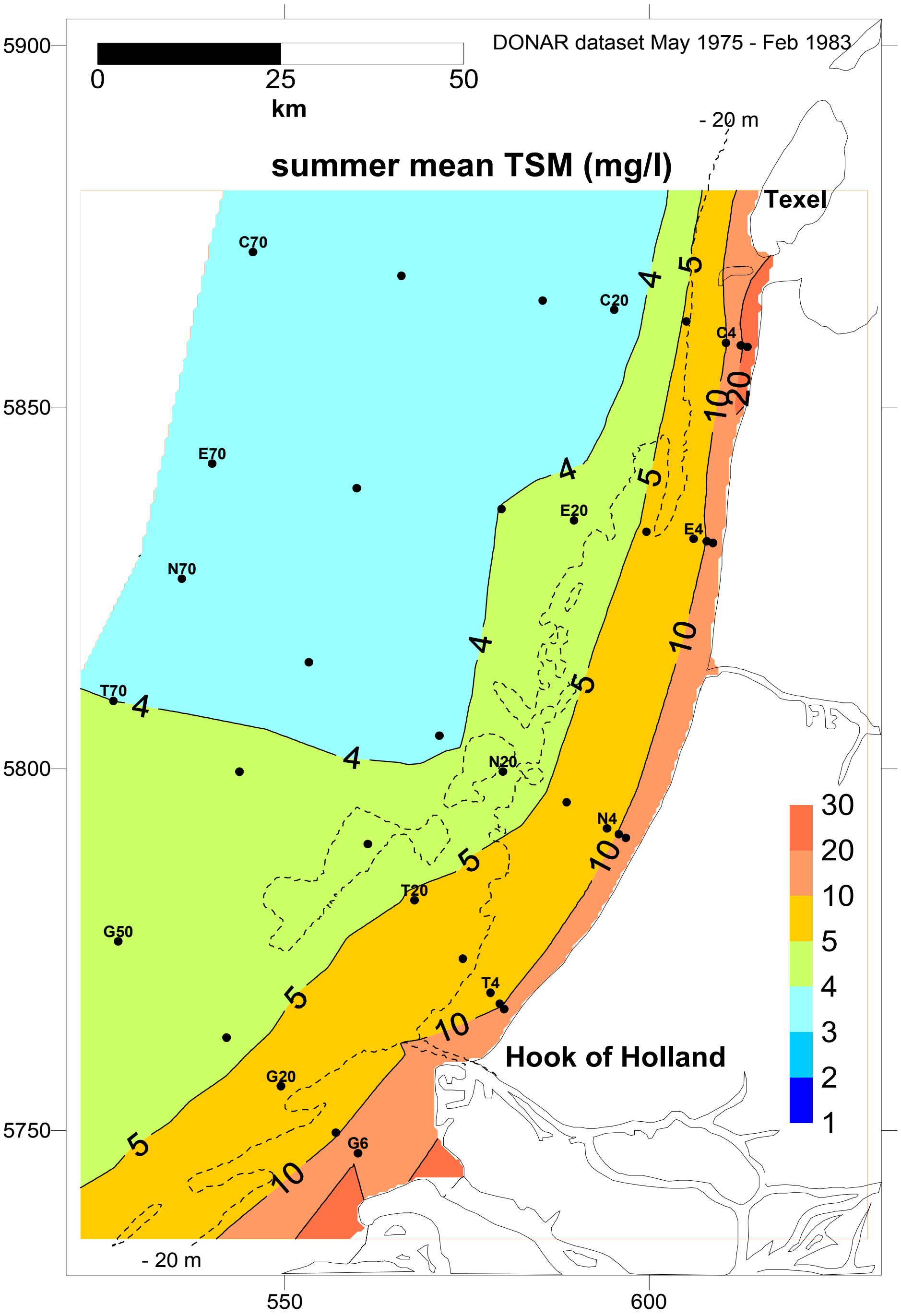


Chart 7 Summer means of near-surface total suspended matter concentrations (Hook of Holland – Texel)

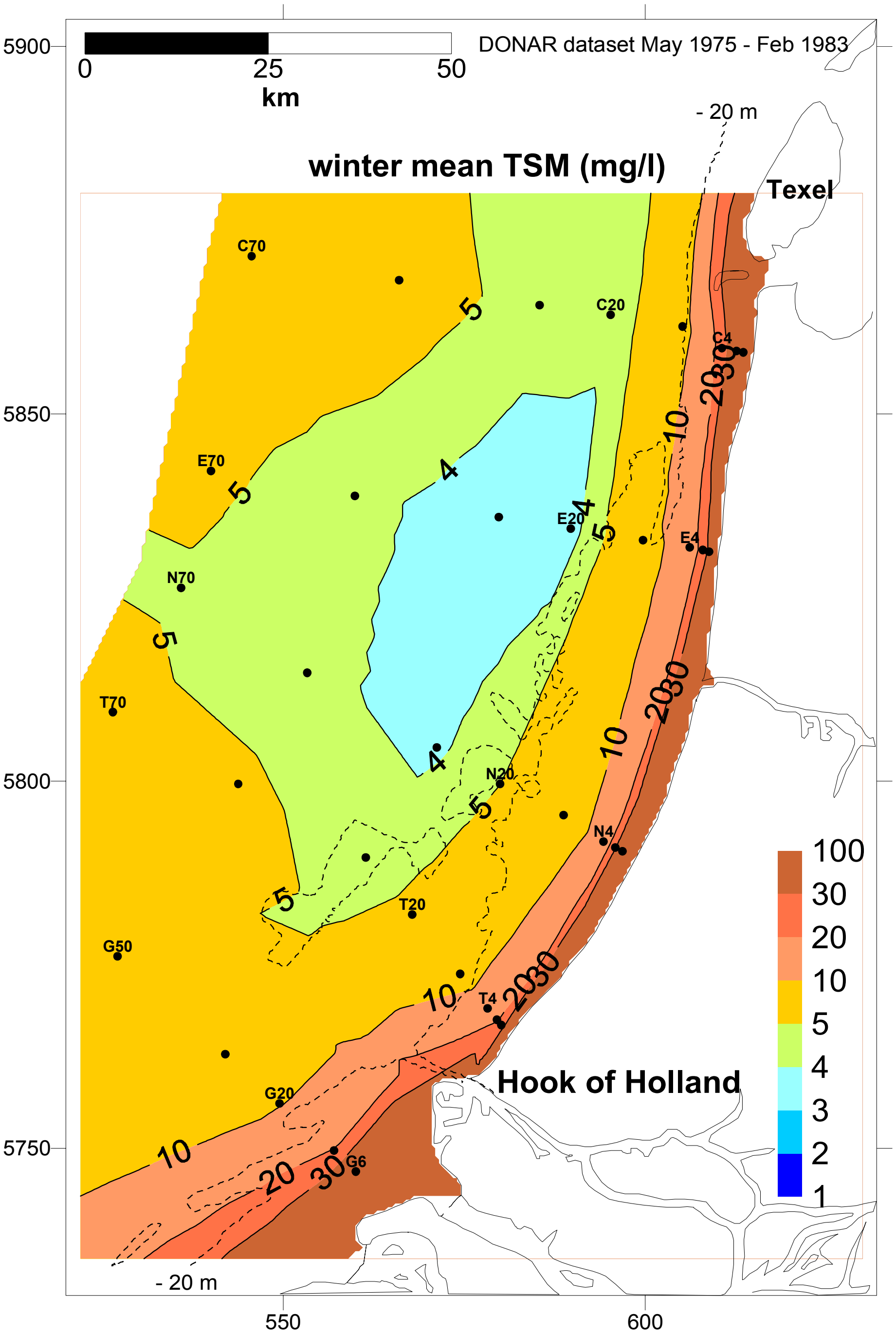


Chart 8 Winter means of near-surface total suspended matter concentrations (Hook of Holland – Texel)

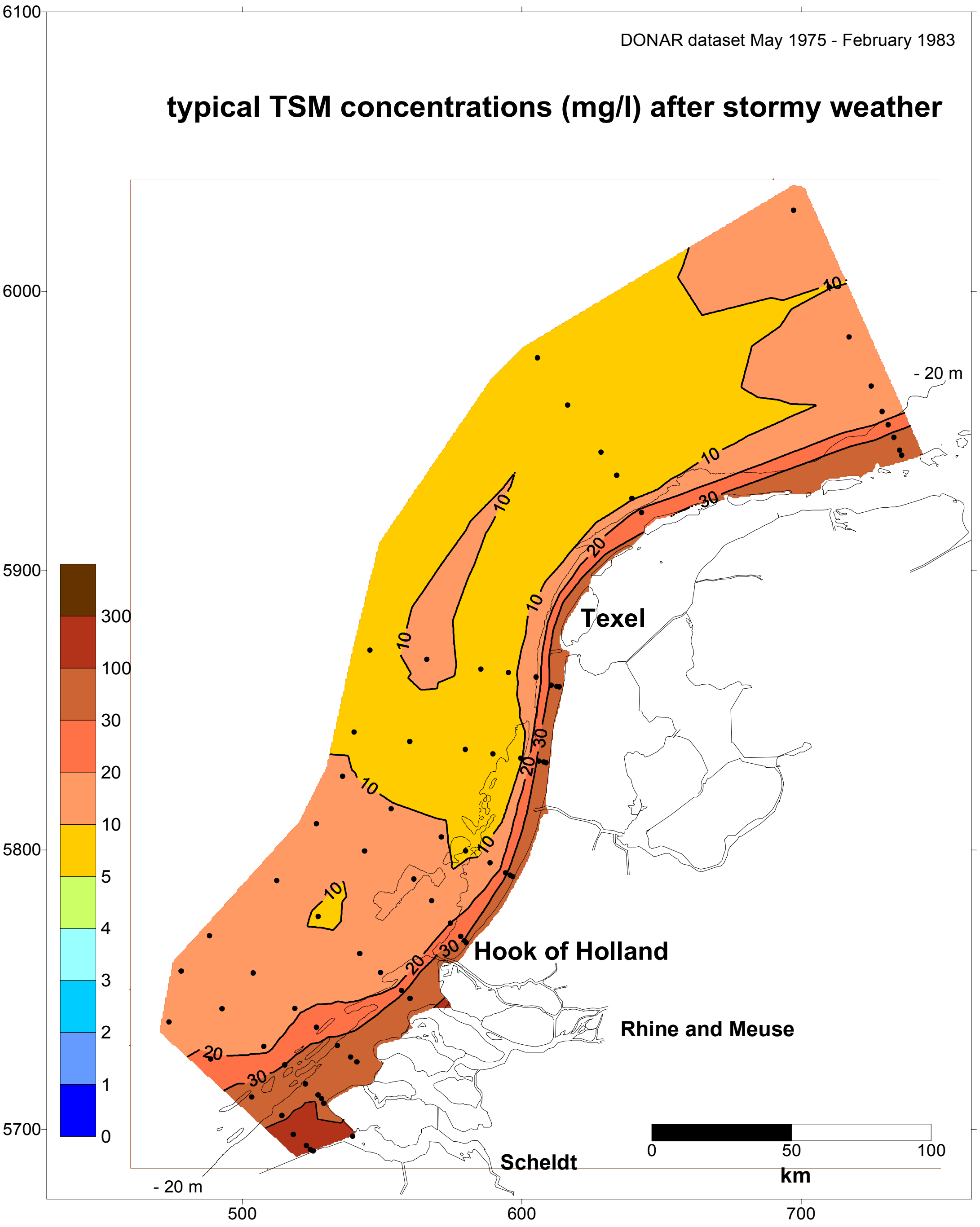


Chart 9 Mean near-surface TSM (mg/l) distribution of the surveys starting on 5 April 1977, 7 January 1981, 9 February 1981 and 23 February 1981. This distribution is representative for situations shortly after stormy weather

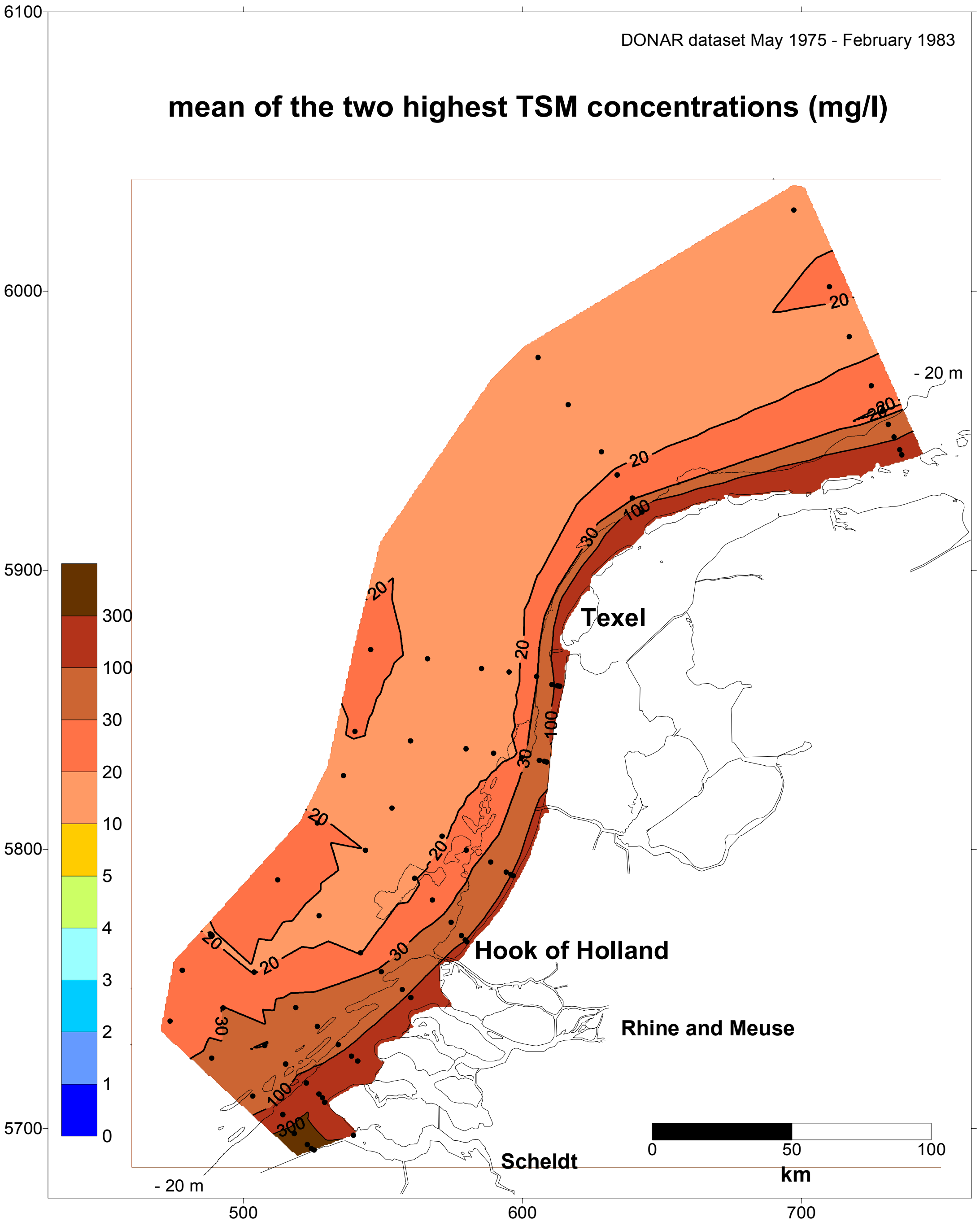


Chart 10 Near-surface TSM (mg/l) distribution based on the mean of the observed two highest values per station

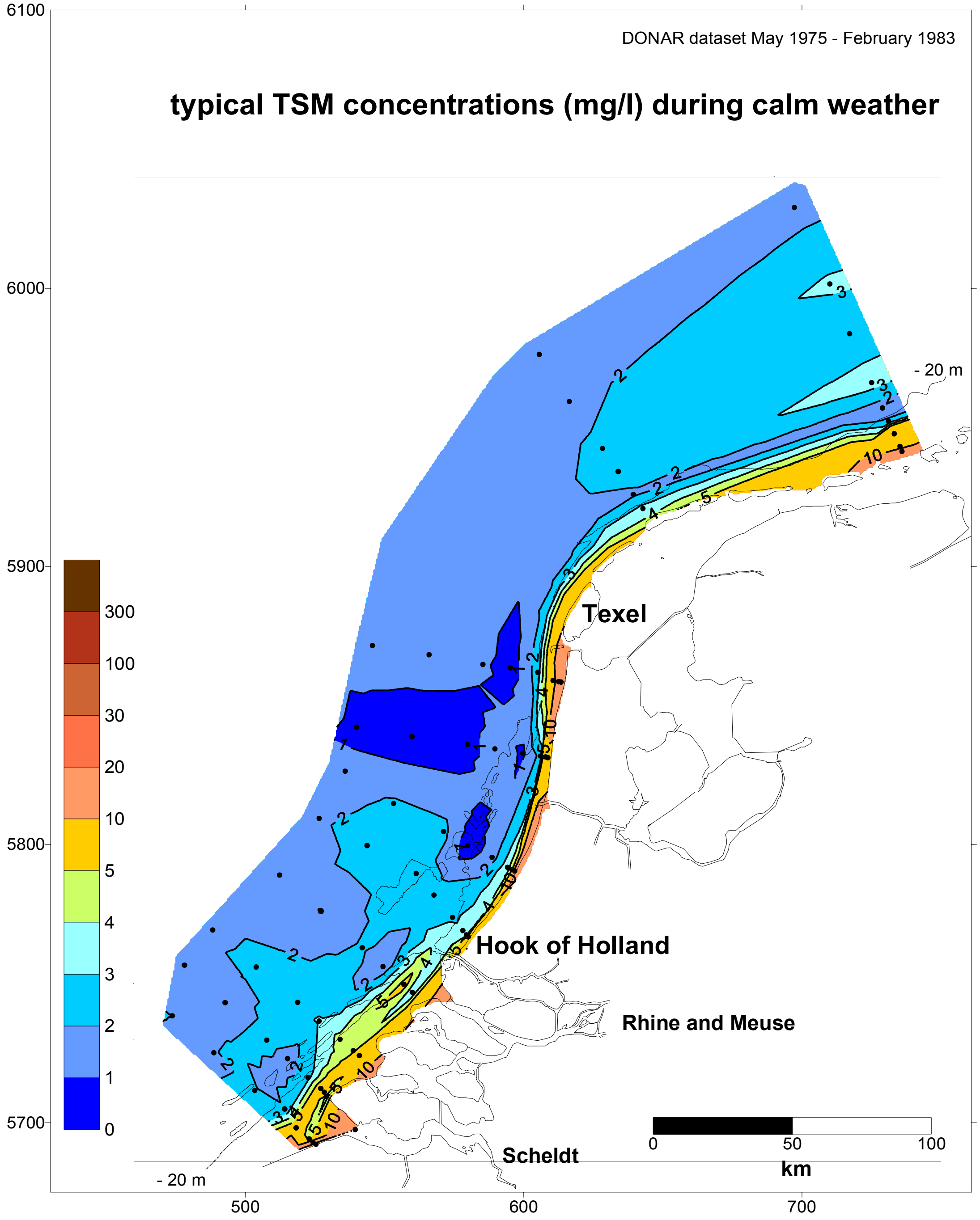


Chart 11 Mean near-surface TSM (mg/l) distribution of the surveys starting on 28 July 1978, 13 July 1981, 7 September 1981, and 17 May 1982. This distribution is representative for situations during calm summer weather

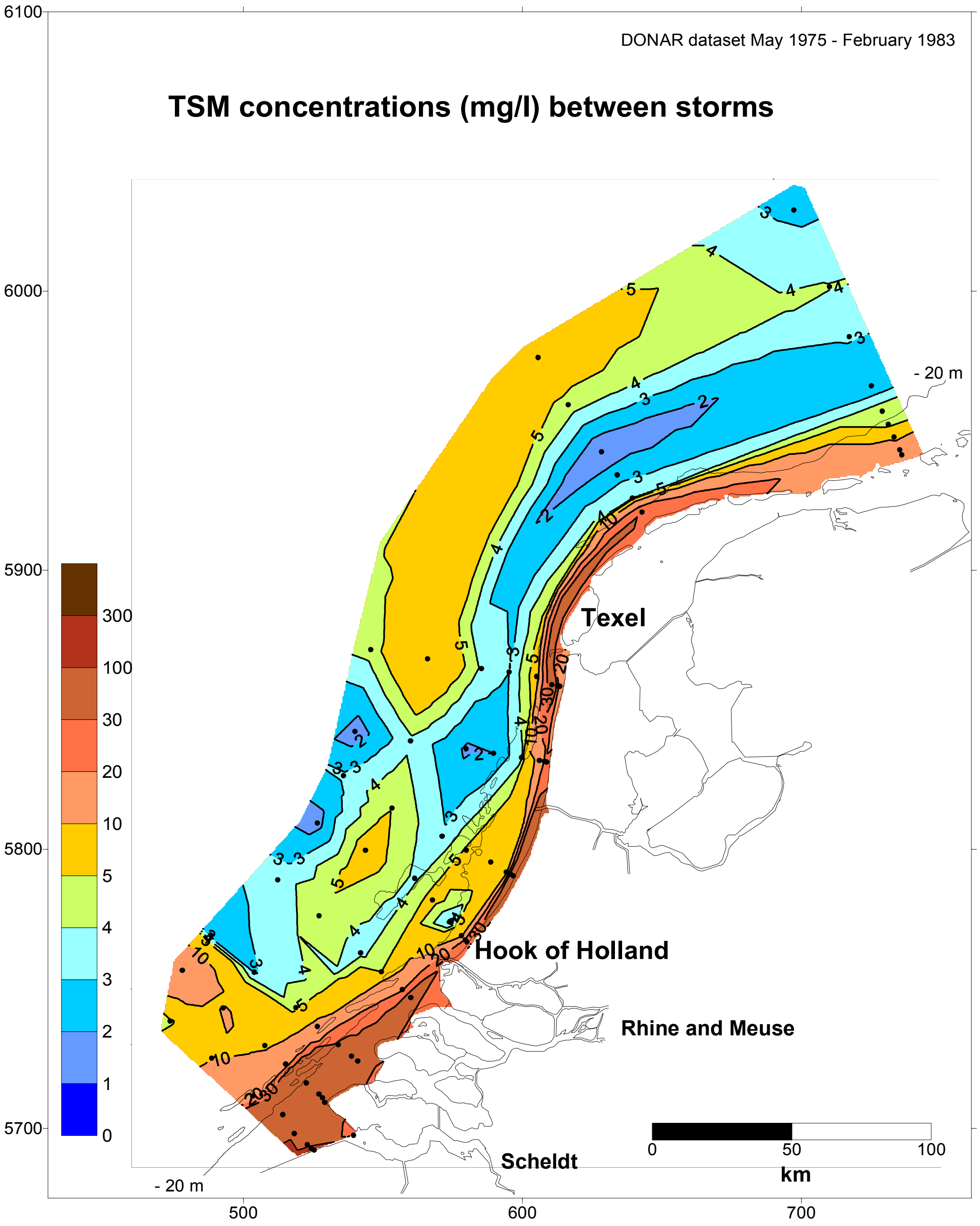
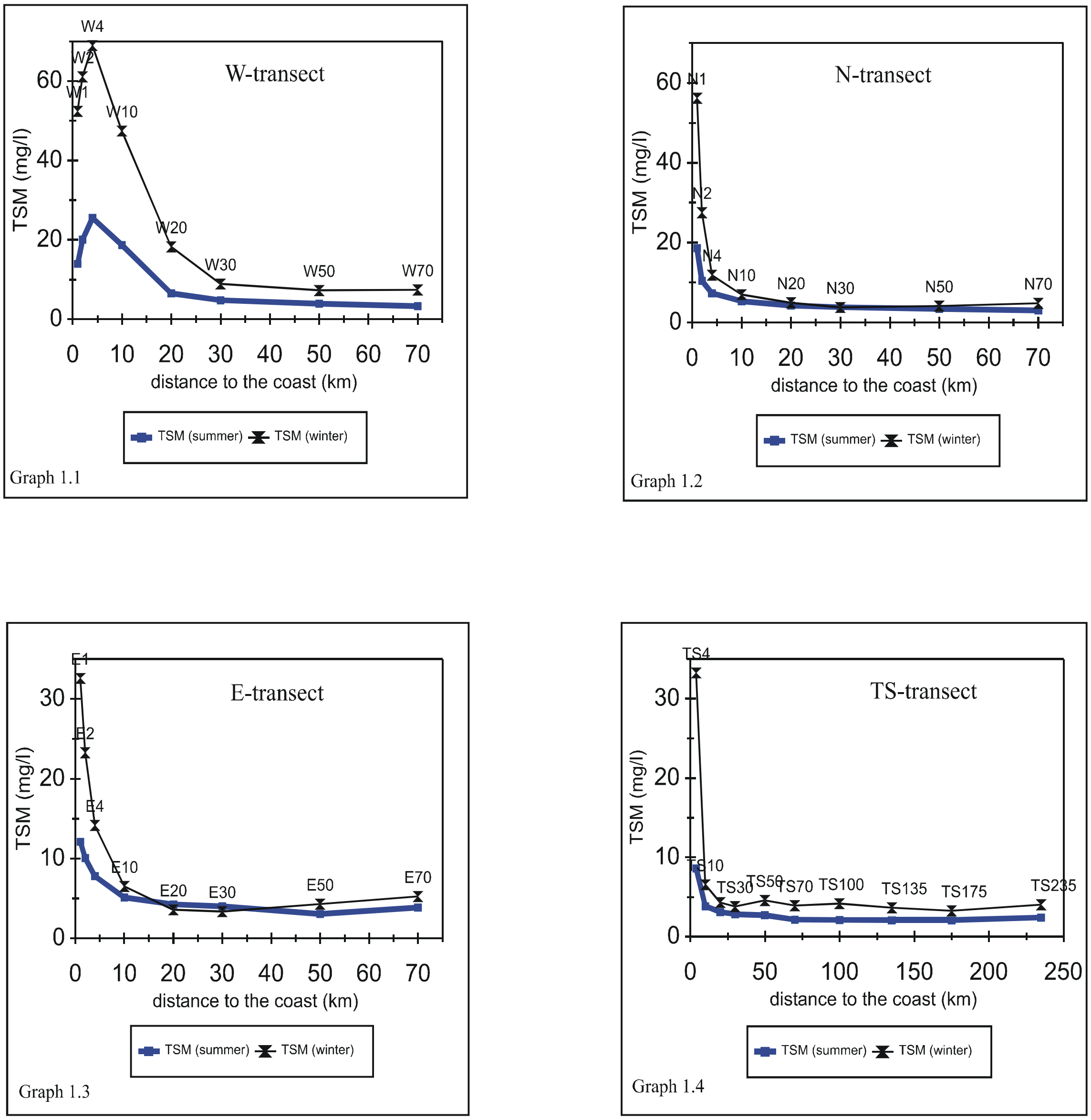
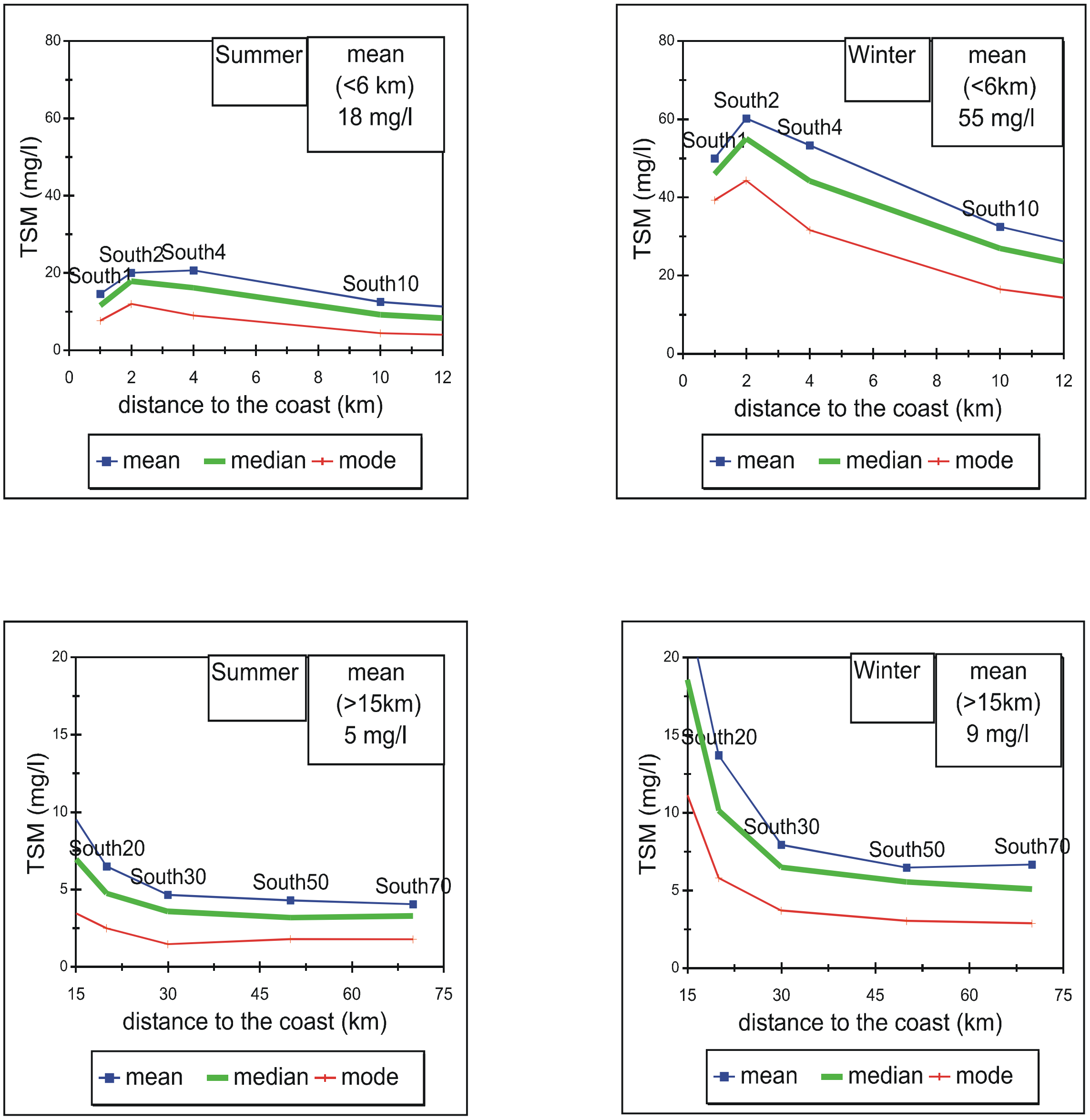


Chart 12 Mean near-surface TSM (mg/l) distribution of the surveys starting on 22 March 1977 and 22 January 1981. The surveys were performed between periods with high TSM values caused by high waves

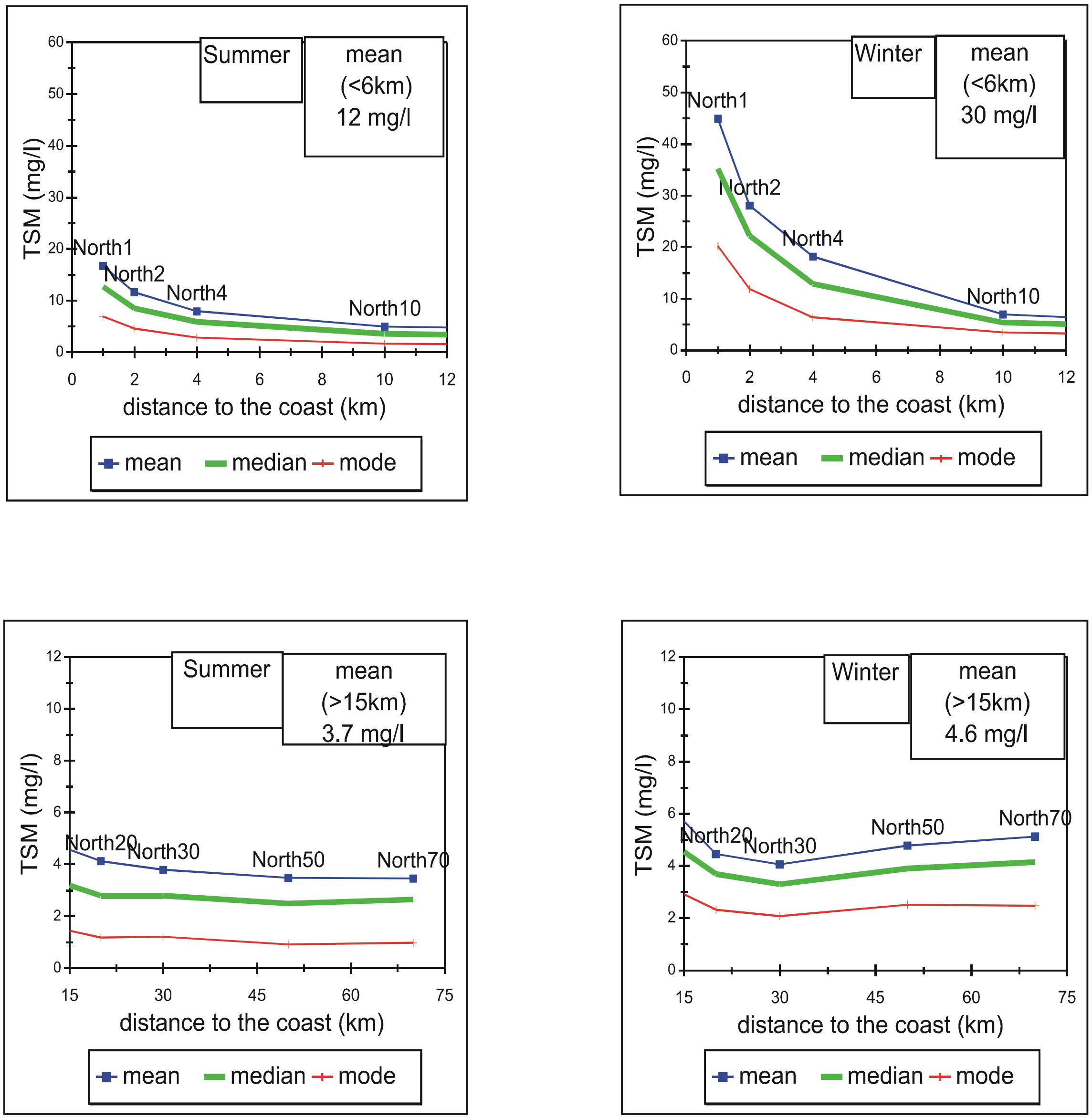
Graphs



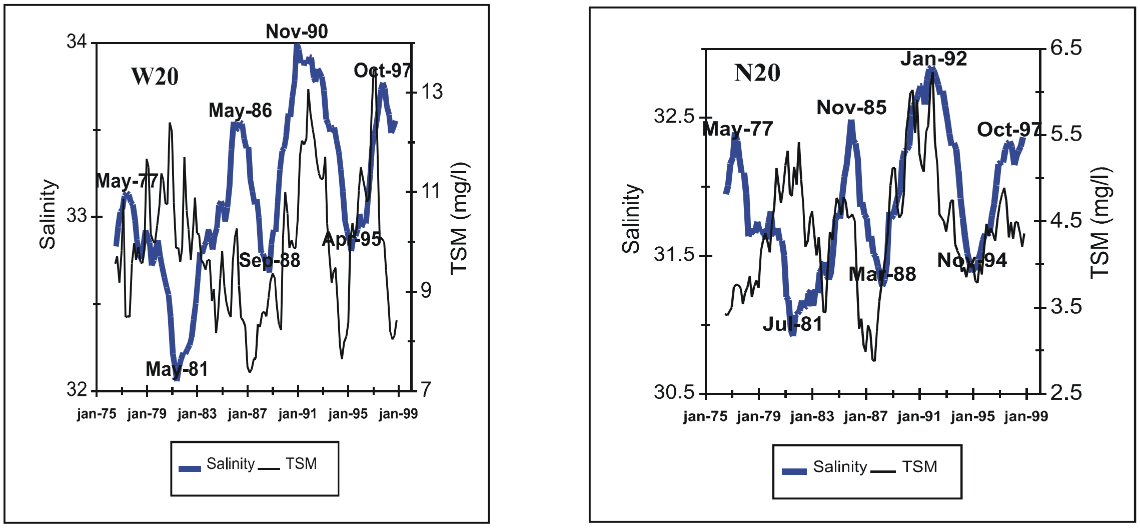
Graph 1 Seasonal mean of near-surface total suspended matter concentrations as a function of cross-shore distance at the W, N, E and TS-transects



Graph 2 Cross-shore dependency of the mean, median and mode of total suspended matter concentrations in the region South, aggregated from the W, S and G-transects. Mean TSM per season and region are shown in the boxes



Graph 3 Cross-shore dependency of the mean, median and mode of total suspended matter concentrations in the region North, aggregated from the T, N, E, C and TS-transects. Mean TSM per season and region are shown in the boxes



Graph 4 Moving averages (2-year window) of the near-surface total suspended matter concentrations and salinity at stations W20 and N20

Tables

Table 1 The statistical parameters of the TSM concentrations (mg/l) for the survey period between May 1975 and February 1983

The DONAR data from 1 May 1979 through 20 Augustus 1979 are not used for the determination of the statistical parameters preventing statistical bias (Suijlen and Duin, 2001). The results at the stations TS100, TS135, TS175 and TS235 are based on available DONAR data between 1988 and 1999

	Summer 1 May – 31 October								Winter 1 December – 31 March							
station	A1	A2	A4	A10	A20	A30	A50	A70	A1	A2	A4	A10	A20	A30	A50	A70
sample size	98	98	98	98	98	98	97	96	51	51	51	51	50	51	49	49
mean	105.4	90.6	40.5	34.0	14.6	6.8	4.5	3.8	267.3	258.2	121.6	136.1	35.9	17.1	8.4	7.1
median	93.6	66.4	36.2	23.7	11.0	5.7	4.1	3.0	228.5	234.5	80.2	90.7	24.4	12.6	6.0	5.1
mode	60.4	36.5	17.0	12.6	5.9	3.9	2.2	1.3	136.7	168.9	43.1	60.4	12.8	7.2	3.3	2.5
variation coef	0.68	0.86	0.87	0.94	0.88	0.71	0.85	0.97	0.76	0.68	0.86	0.73	0.83	0.82	0.84	0.84

station	W1	W2	W4	W10	W20	W30	W50	W70	W1	W2	W4	W10	W20	W30	W50	W70
sample size	94	97	98	98	95	93	74	74	51	51	51	50	50	49	44	43
mean	14.0	20.1	25.5	18.7	6.5	4.8	3.9	3.3	52.4	61.1	69.0	47.4	18.3	8.9	7.3	7.4
median	10.6	17.9	20.1	14.1	4.6	3.5	3.2	3.1	49.0	57.6	63.7	38.6	13.5	6.8	5.7	5.2
mode	7.2	12.0	11.7	6.8	2.3	1.3	1.7	2.1	43.2	46.6	42.5	24.7	8.9	4.5	2.6	3.1
variation coef	0.74	0.69	0.95	0.91	1.10	1.32	0.86	0.74	0.41	0.51	0.64	0.65	0.75	0.76	0.97	0.86

station	S1		S4	S10	S20	S30	S50	S70	S1		S4	S10	S20	S30	S50	S70
sample size	88		88	97	97	97	98	98	41		42	50	50	49	48	48
mean	15.3		16.6	9.8	5.9	4.7	4.4	4.0	46.8		45.7	30.2	13.8	9.5	6.7	6.6
median	12.4		12.2	7.2	4.3	3.7	3.2	3.3	41.8		38.7	28.3	12.9	7.4	5.8	5.7
mode	8.1		7.1	4.3	2.3	1.7	1.7	1.6	32.6		29.6	22.7	7.6	4.6	4.3	3.7
variation coef	0.75		0.85	0.83	0.93	0.97	0.95	0.97	0.53		0.61	0.58	0.72	0.81	0.70	0.74

station			G6	G10	G20	G30	G50	G70			G6	G10	G20	G30	G50	G70
sample size			97	98	98	97	72	73			50	50	50	49	43	43
mean			19.7	9.0	6.6	4.1	4.0	4.6			43.9	20.3	9.6	5.8	5.1	6.4
median			16.0	7.2	5.5	3.0	3.1	3.7			39.7	17.9	6.9	4.8	4.3	4.7
mode			9.0	5.0	2.6	1.2	1.6	1.7			27.7	13.5	4.2	3.3	2.9	2.6
variation coef			0.88	0.72	0.85	1.12	0.96	0.97			0.65	0.61	0.79	0.74	0.73	0.94

station	T1	T2	T4	T10	T20	T30	T50	T70	T1	T2	T4	T10	T20	T30	T50	T70
sample size	96	99	99	99	95	96	95	95	49	49	49	48	47	49	49	48
mean	11.8	8.5	6.5	5.5	5.1	4.4	4.4	4.0	26.9	18.0	11.8	8.5	5.3	4.5	5.3	5.3
median	9.7	6.8	5.9	3.9	3.2	3.0	2.9	3.2	22.3	15.4	10.1	6.4	3.9	3.6	4.0	4.3
mode	5.5	4.8	3.8	1.9	1.4	1.3	1.2	1.3	14.5	8.4	6.2	3.7	2.7	2.5	2.9	3.1
variation coef	0.84	0.76	0.72	0.99	1.09	1.19	1.06	1.10	0.76	0.95	0.78	0.88	0.74	0.72	0.68	0.73

station	N1	N2	N4	N10	N20	N30	N50	N70	N1	N2	N4	N10	N20	N30	N50	N70
sample size	91	96	97	95	97	94	92	92	46	48	49	49	47	48	47	46
mean	18.7	10.5	7.4	5.3	4.3	3.9	3.4	3.0	56.2	27.6	11.9	7.0	5.0	3.8	4.2	4.9
median	14.1	8.6	5.9	4.0	3.3	2.7	2.4	2.6	42.7	23.4	8.7	5.4	3.8	3.4	3.5	4.2
mode	10.1	5.6	3.2	2.1	1.2	1.3	0.87	1.1	25.8	14.7	6.3	3.8	2.7	2.6	2.9	2.8
variation coef	0.72	0.75	0.88	0.96	1.11	1.00	1.16	1.02	0.76	0.71	0.76	0.77	0.73	0.70	0.68	0.72

station	E1	E2	E4	E10	E20	E30	E50	E70	E1	E2	E4	E10	E20	E30	E50	E70
sample size	92	98	98	97	97	94	94	95	46	46	48	48	48	48	48	47
mean	12.1	10.1	7.8	5.1	4.3	4.0	3.1	3.9	32.6	23.3	14.2	6.5	3.6	3.4	4.3	5.3
median	10.6	7.6	5.6	3.3	2.8	3.1	1.8	2.4	31.3	24.3	13.5	4.8	3.1	3.0	3.6	3.8
mode	5.6	4.3	2.5	1.9	1.2	1.0	0.28	0.53	28.8	19.5	9.8	3.2	2.3	2.0	2.6	2.4
variation coef	0.80	0.85	0.96	0.92	1.10	1.14	1.45	1.58	0.43	0.47	0.58	0.75	0.70	0.75	0.65	0.87

station	C1	C2	C4	C10	C20	C30	C50	C70	C1	C2	C4	C10	C20	C30	C50	C70
sample size	85	86	95	93	94	95	94	96	46	46	47	48	48	47	48	48
mean	24.4	18.2	9.6	5.1	3.3	3.3	3.5	3.8	67.4	46.0	22.6	6.5	4.2	4.4	5.8	6.0
median	20.4	12.9	6.5	3.8	2.1	2.7	2.7	3.1	60.9	37.0	20.0	5.6	3.8	3.1	4.4	5.0
mode	12.9	6.0	2.4	1.5	0.72	0.81	0.84	1.1	39.3	21.8	11.1	4.1	2.5	1.8	3.3	3.3
variation coef	0.73	0.95	1.05	1.03	1.12	1.06	1.15	1.00	0.71	0.73	0.74	0.69	0.70	0.83	0.71	0.76

station			TS4	TS10	TS20	TS30	TS50	TS70			TS4	TS10	TS20	TS30	TS50	TS70
sample size			93	94	93	94	93	91			42	42	41	42	41	41
mean			8.6	3.9	3.1	2.8	2.7	2.2			33.3	6.6	4.3	3.8	4.6	3.9
median			6.5	2.9	2.2	2.2	2.0	1.6			20.7	5.4	4.4	3.5	3.0	3.0
mode			2.9	0.88	0.83	0.89	0.78	0.47			11.1	3.0	1.8	1.9	1.6	1.0
variation coef			1.08	1.08	1.14	1.06	1.06	1.20			1.00	0.84	0.91	0.83	0.91	0.98

station					TS100	TS135	TS175	TS235					TS100	TS135	TS175	TS235
sample size					85	86	86	86					37	37	36	35
mean					2.1	2.1	2.1	2.4					4.2	3.6	3.3	4.1
median					1	1	1	1					2	2	2	3
mode					0.77	0.73	0.65	0.70					1.24	0.89	1.03	1.73
variation coef					1.09	1.28	1.37	1.38					1.02	1.29	1.31	0.82

station	R3	R5	R10	R20	R30	R50	R70	R100	R3	R5	R10	R20	R30	R50	R70	R100
sample size	91	89	91	90	90	93	91	90	35	36	40	40	40	41	41	40
mean	30.2	17.5	11.7	3.5	3.9	3.2	3.3	2.8	58.7	32.5	21.5	5.7	4.5	5.0	3.8	4.3
median	20.2	10.1	7.7	2.3	2.8	2.3	2.3	1.7	43.6	33.7	18.6	4.3	3.4	3.8	2.6	2.6
mode	9.9	4.2	3.4	0.9	1.2	1.0	0.93	0.59	28.5	30.4	15.8	2.1	2.5	2.4	1.8	0.78
variation coef	1.01	1.27	1.26	1.01	1.07	0.99	1.17	1.09	0.77	0.42	0.58	0.89	0.74	0.80	0.78	1.07

Table 2 The statistical parameters of the TSM concentrations (mg/l) at the aggregated stations for the survey period between May 1975 and February 1983

The DONAR data from 1 May 1979 through 20 Augustus 1979 are not used for the determination of the statistical parameters preventing statistical bias (Suijlen and Duin, 2001)

South = data of W, S and G transects at the same distance to the coast
North = data of T, N, E, C and TS transects at the same distance to the coast

Summer 1 May – 31 October

Winter 1 December – 31 March

Lwinter 1 November – 30 April

	South								
	Summer	Summer	Summer	Summer	Summer	Summer	Summer	Summer	
	South1km	South2km	South4km	South10km	South20km	South30km	South50km	South70km	
sample size	183	97	283	293	284	281	237	239	
mean	14.6	20.1	20.7	12.6	6.5	4.7	4.3	4.1	
median	11.6	17.9	16.2	9.2	4.8	3.6	3.2	3.3	
mode	7.7	12.0	9.1	4.4	2.5	1.5	1.8	1.8	
variation Coef	0.75	0.69	0.93	0.98	0.94	1.12	0.90	0.91	
	South								
	Winter	Winter	Winter	Winter	Winter	Winter	Winter	Winter	
	South1km	South2km	South4km	South10km	South20km	South30km	South50km	South70km	
sample size	92	51	143	150	150	147	128	133	
mean	50.0	60.2	53.3	32.5	13.7	7.9	6.5	6.7	
median	46.0	55.1	44.2	27.0	10.2	6.5	5.6	5.1	
mode	39.3	44.4	31.7	16.5	5.8	3.7	3.1	2.9	
variation Coef	0.46	0.52	0.68	0.75	0.82	0.82	0.81	0.86	
	South								
	Lwinter	**Lwinter**	**Lwinter**	**Lwinter**	**Lwinter**	**Lwinter**	**Lwinter**	**Lwinter**	
	South1km	South2km	South4km	South10km	South20km	South30km	South50km	South70km	
sample size	141	79	220	232	232	227	198	202	
mean	42.8	50.1	47.6	27.6	12.0	7.1	5.6	6.1	
median	37.8	42.1	39.3	22.5	9.4	5.6	4.5	4.5	
mode	31.8	29.9	28.5	13.1	4.8	3.4	2.6	2.6	
variation Coef	0.52	0.59	0.69	0.79	0.87	0.82	0.84	0.86	
	South								
	ratio	between	Winterand	Lwinter	values				transectmean
ratio means	1.17	1.20	1.12	1.18	1.14	1.12	1.15	1.10	1.15
ratio medians	1.22	1.31	1.12	1.20	1.09	1.16	1.25	1.15	1.19
	North								
	Summer	Summer	Summer	Summer	Summer	Summer	Summer	Summer	
	North1km	North2km	North4km	North10km	North20km	North30km	North50km	North70km	
sample size	363	376	478	467	455	454	450	450	
mean	16.8	11.7	8.0	5.0	4.1	3.8	3.5	3.5	
median	12.7	8.6	5.9	3.6	2.8	2.8	2.5	2.7	
mode	7.0	4.6	2.9	1.7	1.2	1.2	0.92	1.0	
variation Coef	0.85	0.96	0.98	0.98	1.10	1.08	1.15	1.21	
	North								
	Winter	Winter	Winter	Winter	Winter	Winter	Winter	Winter	
	North1km	North2km	North4km	North10km	North20km	North30km	North50km	North70km	
sample size	189	192	237	235	226	228	231	224	
mean	44.9	28.1	18.2	7.0	4.5	4.1	4.8	5.1	
median	35.2	22.3	12.9	5.4	3.7	3.3	3.9	4.2	
mode	20.2	11.9	6.4	3.5	2.3	2.1	2.5	2.5	
variation Coef	0.84	0.85	1.05	0.80	0.75	0.78	0.74	0.80	
	North								
	Lwinter	**Lwinter**	**Lwinter**	**Lwinter**	**Lwinter**	**Lwinter**	**Lwinter**	**Lwinter**	
	North1km	North2km	North4km	North10km	North20km	North30km	North50km	North70km	
sample size	276	285	358	354	343	346	344	338	
mean	39.8	25.7	17.2	6.7	4.5	4.1	4.6	4.8	
median	31.6	19.3	12.3	5.4	3.7	3.3	3.6	3.7	
mode	16.7	11.0	6.4	3.4	2.2	1.9	2.1	2.1	
variation Coef	0.87	0.85	1.01	0.78	0.78	0.83	0.80	0.84	
	North								
	ratio	between	Winterand	Lwinter	values				transectmean
ratio means	1.13	1.09	1.06	1.04	0.99	0.99	1.04	1.07	1.05
ratio medians	1.11	1.15	1.05	1.01	1.00	1.00	1.08	1.12	1.07