ICES Journal of Marine Science, 53: 926–932. 1996

The North-West European Shelf Programme (NOWESP): integrated analysis of shelf processes based on existing data sets and models

Wim van Leussen, Günther Radach,
Wim van Raaphorst, Franciscus Colijn, and
Remi Laane

Van Leussen, W., Radach, G., Van Raaphorst, W., Colijn, F., and Laane, R. 1996. The North-West European Shelf Programme (NOWESP): integrated analysis of shelf processes based on existing data sets and models. – ICES Journal of Marine Science, 53: 926–932.

An overview is presented of the North-West European Shelf Programme, including objectives, aspects of database management, time-series analysis, and analysis of spatial distribution of various parameters. Examples of some results are given.

Key words: database, NOWESP, shelf seas, spatial distribution, suspended particulate matter, time series.

W. van Leussen and R. Laane: National Institute for Coastal and Marine Management, PO Box 20907, 2500 EX The Hague, The Netherlands. G. Radach: Universität Hamburg, Institut für Meereskunde (IfM), Troplowitzstrasse 7, 22529 Hamburg, Germany. W. van Raaphorst: Netherlands Institute for Sea Research, PO Box 59, 1790 AB Den Burg, Texel, The Netherlands. F. Colijn: Forschungs- und Technologiezentrum Westküste, Hafentörn, 25761 Büsum, Germany.

Introduction

Shelf seas and their edges are vital parts of the global marine environment. They represent highly productive ecosystems and, on a global scale, their sediments may provide important sinks for carbon and other elements (Walsh, 1988, 1991). In addition, shelf seas are under pressure from increasing human activities, e.g. fisheries and discharge of compounds. An understanding of the functioning of shelf seas and the factors controlling their variability and trends is thus of major importance for improving our insight into the global marine system.

The north-west European Shelf includes the North Sea, Skagerrak, Kattegat, Irish Sea, Celtic Sea, the English Channel, and several adjacent water bodies between the European Continent, the British Isles, and the Atlantic Ocean 200 m depth contour (Fig. 1). The shelf can be viewed as the transit region to the Atlantic Ocean for dissolved and particulate matter stemming from major European rivers, and for organic matter produced on the shelf. Many research cruises as well as numerical models have produced substantial knowledge on the functioning of the shelf. The combination of observational data and modelling results yields one of the most detailed sets of information available for the world shelf seas.

Available data span a relatively short period of several decades. The variability observed during this period is often difficult to interpret because of interference with long-term changes in the global environment (Becker and Otto, 1990). Water temperature on the shelf is largely controlled by the Atlantic Gulf Stream. Changes in route or strength of the Gulf Stream, which are directly related to atmospheric circulation, directly influence the biota on the shelf (Mann and Lazier, 1991; Taylor *et al.*, 1992). Thus, long-term changes observed in nutrients (Brockmann *et al.*, 1990; Gerlach, 1990; Hickel *et al.*, 1993; Laane *et al.*, 1996), phytoplankton and zooplankton (Colebrook, 1975, 1986; Fransz *et al.*, 1991; Dickson *et al.*, 1988; Gerlach, 1990; Uhlig and Sahling, 1990; Hickel *et al.*, 1993, 1994), and fish stocks (Hempel, 1978; Corten, 1990; Daan *et al.*, 1991) can probably be well understood only in the light of variability in the hydrography of the Atlantic Ocean and climate (Aebisher *et al.*, 1990; Lindeboom *et al.*, 1994).

The central theme of the NOWESP project (North-West European Shelf Programme) is to analyse existing data sets of the shelf accumulated from a large number of European research institutes. The objective is to describe and understand the function and role of the north-west European Shelf as a link between land and

1054–3139/96/060926+07 $18.00/0

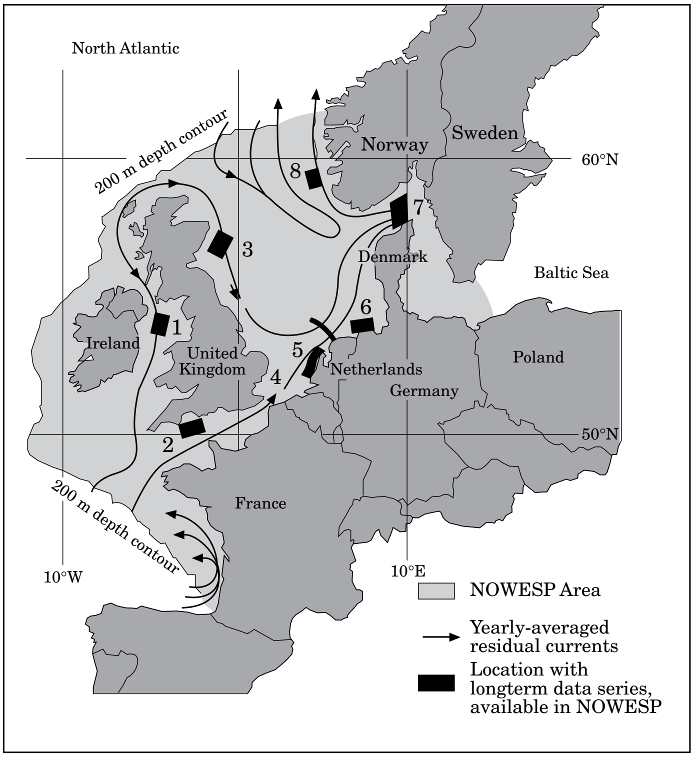

Figure 1. Map of the north-west European shelf. Eight locations are indicated for which time series spanning more than 20 years are available in the NOWESP research database. Arrows indicate the average residual current field on the shelf.

ocean on the basis of a combination of existing data and available transport models. Within this overall objective, two specific aims are defined: to estimate (1) the variability and trends in water movements, concentrations of particulate and dissolved constituents, and primary production on the shelf, and (2) the fluxes and transports of relevant substances, such as suspended particulate matter, nutrients and plankton, across the shelf. In a sense, NOWESP is aimed at examining how much more information can be gained from the extensive research activities in the past, and whether this information can be interpreted or understood.

The present contribution focuses on the basic concepts and research strategies of NOWESP, exemplified by representative results. The most crucial part in the project is bringing together the relevant data sets and making these available for further analysis. Other topics described here concern the analysis of time-series data and spatial distribution of specific parameters on the shelf. More detailed discussions of results obtained in NOWESP are presented in this volume by Laane *et al.* (1996) and Bot and Colijn (1996).

Data management

All data relevant to NOWESP are banked in the ORACLE relational database system at the Institut für Meereskunde (IfM) of Hamburg University. This database is part of the general Ecological Modelling Database (ECOMOD; Lenhart *et al.*, 1995) running on SUN Sparc work stations. The database organization is founded on tables related to each other by means of a scheme developed especially for storing marine data of any kind (physical, chemical and biological observations, modelling results, originators, measuring methods, modelling and sampling details, etc.). The possibility of grouping data from different sources for specified spatial and temporal windows makes this tool suitable for the objectives stated.

To estimate fluxes, data on concentrations have to be combined with hydrodynamic information, although experimental data on current fields are available for a limited number of locations only. Therefore, results from numerical models (e.g. advection and dispersion) calibrated for actual meteorological conditions are included in the database.

Time-series data of current measurements, salinity, temperature, nutrients (N, P, and Si), organic matter, suspended matter, phyto- and zooplankton and chlorophyll are accumulated and stored in the research database. At May 1995, the database contained more than 2.2×10^6 data records, taking up $\sim$740 MB of storage capacity. The records include $\sim90\times10^4$ physical data, $\sim41\times10^4$ nutrient data, $\sim14\times10^4$ data on suspended

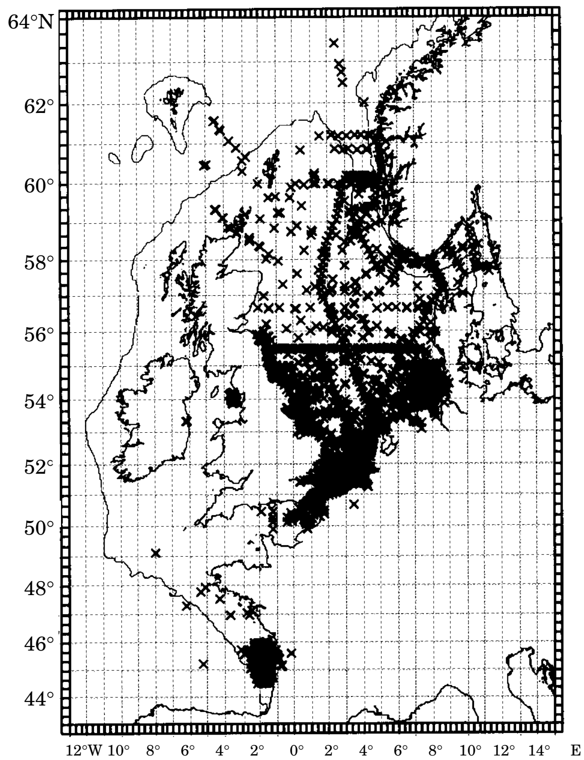

Figure 2. Map indicating the spatial distribution of all suspended matter data available in the NOWESP research database.

particulate matter, $\sim 13 \times 10^4$ chlorophyll data, $\sim 50 \times 10^4$ phyto- and zooplankton data, and $\sim 65 \times 10^5$ measurements of miscellaneous parameters. Data reports giving an overview of relevant properties of the stored information are provided to all NOWESP partners (see Fig. 2 for an example).

Quality control on the data is fundamental in meeting the objectives. In principle, this control is performed by the data originators, but subsequent control is carried out by the partners delivering the data and by the data managers at IfM. Some data sets partly overlap and these can be tested for mutual consistency. In this way, obvious errors and omissions have been found and restored or eliminated.

Time-series analysis

By combining a large number of existing data sets (Gekeler and Radach, 1994) and the joint application of modern statistical analysis techniques (Van Leussen and Radach, 1994), "new" time-series information has been created from "old" data. Time series of various parameters spanning over more than 20 years are available for eight fairly widespread locations (Fig. 1, Table 1), which mark characteristic features of the residual current field of the shelf. As an example we show time series of salinity in surface waters at stations 2 and 5 (Fig. 3). Station 2 (E1 near Plymouth) reflects largely oceanic water with high salinity and minor seasonal variation. Periods of enhanced salinity are found in the late 1960s, while the winters of 1978–1979 and 1982–1983 were characterized by relatively low salinities. Similarly low salinities were observed in the Skagerrak (Station 7, Fig. 1) between 1978 and 1981 (Svendsen and Danielssen, 1995). The timing of these low salinities corresponds well with the route of the great salinity anomaly through the Atlantic Ocean (Mann and Lazier, 1991).

Station 5 near Helgoland is representative of coastal waters strongly influenced by river outflow. Thus, salinity is dominated by seasonal variations with less saline water in spring and early summer when the discharge of the river Elbe is at maximum. The influence of the great salinity anomaly is not apparent in this time series. However, when plotting the residual of the long-term mean value and the actual salinity, a 3-year period of relatively low salinity was observed between 1979 and 1982 (Schultz, 1995). Similar results are obtained for stations near the Dutch coast (Laane *et al.*, 1996).

These results illustrate the impact of the Atlantic Ocean on the salinity of shelf surface waters. Within NOWESP, time series are further analysed to gain insight into the effects on for example nutrient concentrations and levels of chlorophyll. For results of these analyses we refer to Laane *et al.* (1996) and Bot and Colijn (1996).

Spatial distribution analysis

Spatial distributions of temperature, salinity, nutrients, suspended particulate matter, chlorophyll, and primary production have been reviewed in the past on the basis of single data sets for parts of the north-west European Shelf, particularly the North Sea (e.g. Eisma and Kalf, 1987; Otto *et al.*, 1990; Brockmann *et al.*, 1990; Charnock *et al.*, 1993; Sündermann, 1994). Although these reviews have proved to be of great value to understanding the functioning of the shelf, these spatial data sets have several limitations (Bohle-Carbonell, 1994). The most important ones are (1) inhomogeneous areal coverage, (2) quasi-synoptic data collection in time, (3) loss of information and misinterpretation due to smoothing and interpolation of data. In dealing with these three problems, our approach to optimal utilization of the available data is illustrated by taking suspended particulate matter as an example.

The largest fraction of the total number of 138 415 records of suspended matter measured at 4066 locations is originating from the North Sea, particularly from the southern parts (Fig. 2). Spatial analysis is therefore

Table 1. Description of eight locations for which time series spanning more than 20 years are available in the NOWESP research database. (S=salinity; T=temperature; N=dissolved inorganic phosphorus and nitrogen; C=chlorophyll; M=suspended matter and particulate organic carbon.)

No.	Location	Position* Longitude	Position* Latitude	Period	Parameters
1	Port Erin	05°00′W – 04°00′W	53°25′N – 54°10′N	1955–1994	S, T, N, C
2	E1 – Plymouth	05°00′W – 03°00′W	49°00′N – 50°10′N	1903–1987	S, T, N, C
3	Aberdeen	02°15′W – 00°15′W	56°30′N – 57°30′N	1960–1990	S, T, N, C
4	Belgian coast	02°25′E – 03°27′E	51°00′N – 51°52′N	1977–1992	S, T, N, C, M
5	Dutch coast	02°18′E – 04°28′E	52°02′N – 52°42′N	1973–1993	S, T, N, C, M
6	Helgoland	06°40′E – 08°00′E	54°00′N – 54°45′N	1962–1993	S, T, N, C
7	Skagerrak	07°30′E – 10°30′E	57°00′N – 58°30′N	1968–1994	S, T, N, C
8	Norwegian coast	03°00′E – 05°00′E	58°00′N – 61°00′N	1940–1994	S, T

*Approximation: for precise conditions, see Gekeler and Radach (1994).

restricted to the North Sea. Suspended-matter data span the period between 1960 and 1994, but the majority of the data have been collected after 1976. Apparently, measurements have been spread homogeneously over the seasons.

Although concentrations up to 991 mg l^{-1} have been observed, 95% of the values were below ca. 100 mg l^{-1}, and the median of all values is below 20 mg l^{-1}. Very high values may either be erroneous or represent local turbid conditions which are largely restricted to estuarine and inshore areas. Since these areas are of less interest to NOWESP, values >200 mg l^{-1} are ignored in further analyses.

The different institutes that have submitted measurements of suspended matter have often applied different methods. The method most frequently used to seawater filtration followed by drying and weighing of the material left on the filters. However, different filter types have been used with nominal pore sizes between 0.4 and 1.2 μm, and different periods and temperatures have been applied in the drying process. Some of the measurements were obtained by means of optical instruments, either transmissometers or sensors to measure backscattering. Optical data were all calibrated using data obtained by filtration. The variety of techniques used undoubtedly causes structural differences between subsets within the database. However, as a starting point we assume that these differences are small compared to the *in situ* variability of suspended matter, which is generally high due to patchiness in time and space, and therefore all data have been merged in the analysis.

As a typical example, we examined weeks 2 to 4 of 1991 and merged all available data from surface water samples collected during this 3-week period. What appears is a cluster of data points near the Belgian coast, five transects off the Dutch coast and two rectangular transects in the German Bight. Smoothing the data by distance-weighted interpolation yields a distribution pattern with highest concentrations in the south and lower ones in the north (Fig. 4a). The well-documented steep gradient perpendicular to the continental coastline (e.g. Postma, 1981; Van Alphen, 1990; Visser *et al.*, 1991) is clearly absent in the smoothed distribution of suspended matter.

The NOAA composite reflectance image for the same weeks indicates considerable variance in the Southern Bight and high reflectance along the Belgian and Dutch coasts, along the southern British coast and in the inner German Bight (Fig. 4b). These patterns are not shown by the interpolated suspended matter distribution, because sampling intensity has been too low and coverage of the area has been inhomogeneous. Inspection of the original data, however, revealed that values were generally higher close to the coast than offshore. Apparently, the gradients have disappeared due to the smoothing and interpolation process for this particular data set.

To overcome this problem, the information obtained from the NOAA reflectance image was used in the interpolation procedure. Assuming that the image mirrors the important patterns in suspended matter distribution rather than absolute concentrations, information on the gradients in reflectance was combined with the distance between sampling locations to calculate the weighting factors for interpolation of the *in situ* data. Thus, weighting factors in the direction perpendicular to the reflectance gradients, e.g. parallel to the coastline and along the "plume" originating from the British coast, are higher than along the gradients. By applying this approach, high suspended-matter concentrations are revealed close to the Belgian and Dutch coasts and a much more realistic distribution is obtained than by means of distance-weighted interpolation only (Fig. 4c). Similar approaches can be applied to spatial distributions of for example nutrients and chlorophyll as well. For such parameters, modelled current fields available from the database seem well suited as input for calculating spatial weighting factors.

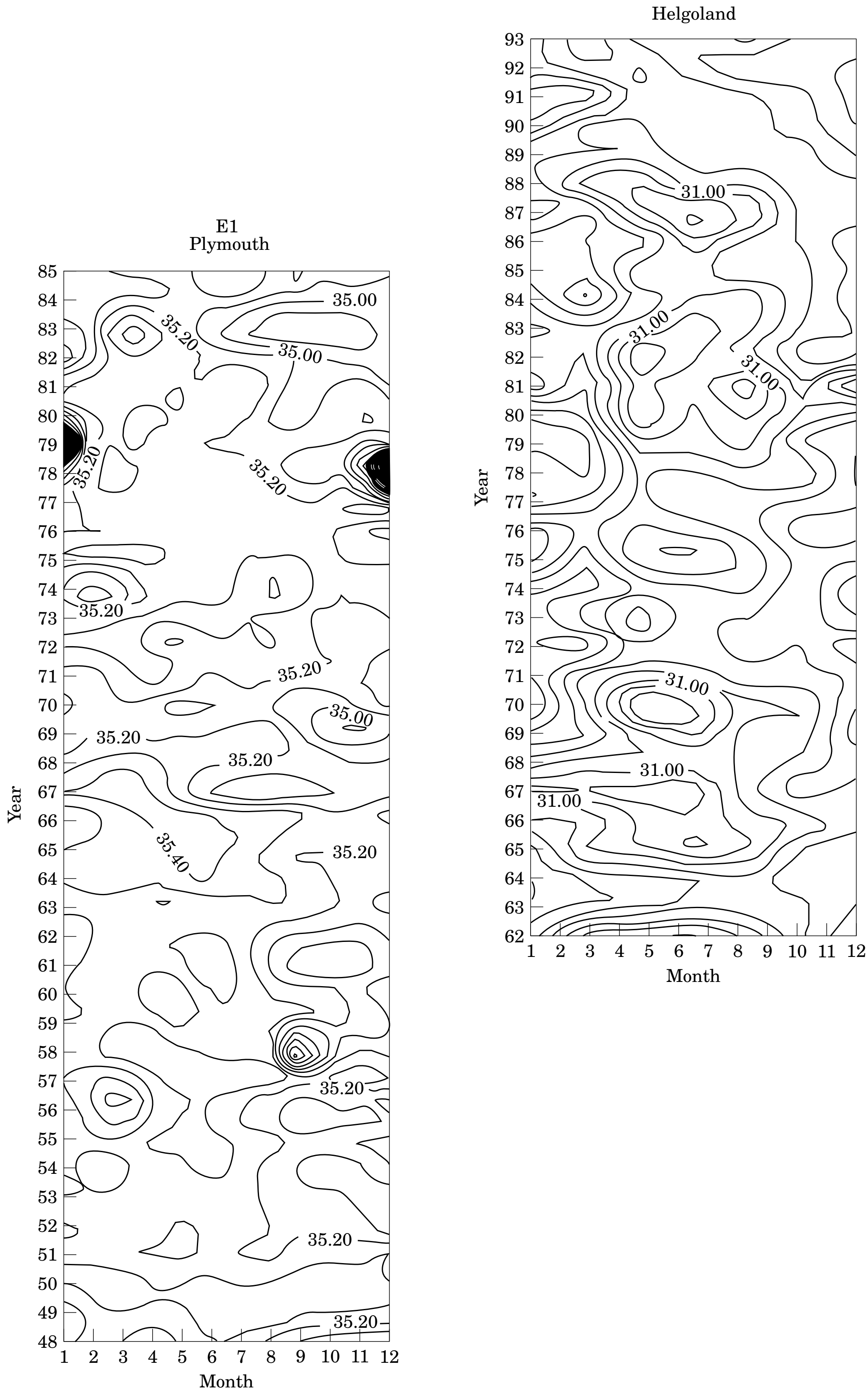

Figure 3. Time series of surface water salinity at Stations 2 (E1 near Plymouth) and 5 (Helgoland).

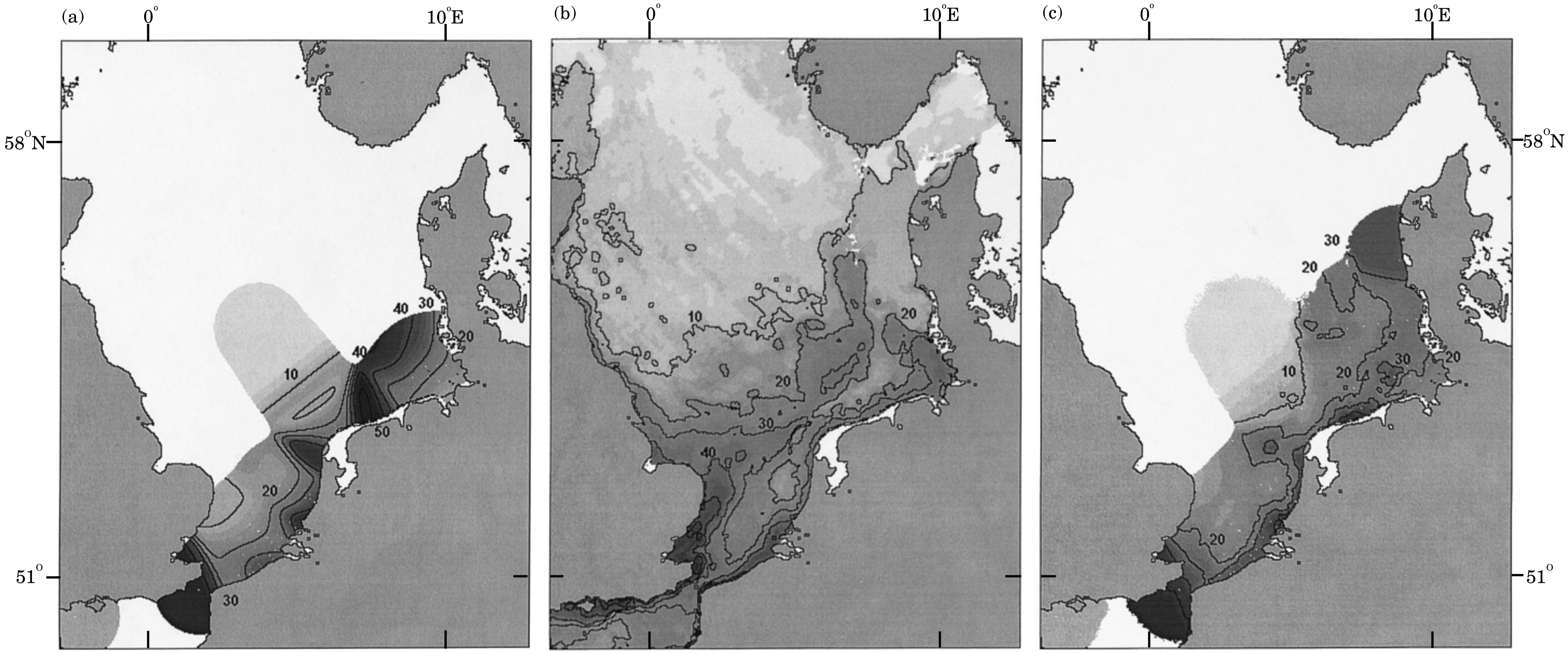

Figure 4. Spatial distribution of suspended particulate matter (SPM) in surface water of the continental coast in weeks 2–4 of 1991. Small white dots indicate the location of the data points. (a) Distribution of SPM based on distance-weighted interpolation; (b) NOAA composite reflectance image for week 3 in 1991. Reflectance was multiplied by a constant factor of 26.6 to arrive at comparable values; (c) Distribution of SPM based an interpolation procedure, which takes both distance reflectance gradients into account.

Acknowledgements

This work has been carried out within the NOWESP project in the Marine Science and Technology programme of the EC (MAST II): MAS2-CT93-0067.

References

Aebisher, N. J., Coulsen, J. C., and Colebrook, J. M. 1990. Parallel long-term trends across four marine trophic levels and weather. Nature, 347: 753–755.

Becker, G., and Otto, L. 1990. Physical Oceanography of the North Sea, Part 4. Long-term variations. Netherlands Journal of Sea Research, 26: 225–238.

Bohle-Carbonell, M. 1994. On the reliability of our North Sea assessment. *In* Circulation and contaminant fluxes in the North Sea, pp. 620–638. Ed. by J. Sündermann. Springer, Berlin.

Bot, P. V. M., and Colijn, F. 1996. A method to estimate primary production from chlorphyll concentrations: consequences for trends in the Irish Sea and the Dutch coastal zone. ICES Journal of Marine Science, 53: 945–950.

Brockmann, U. H., Laane, R. W. P. M., and Postma, H. 1990. Cycling of nutrient elements in the North Sea. Netherlands Journal of Sea Research, 26: 239–264.

Charnock, H., Dyer, K. R., Huthnance, J. M., Liss, P. S., Simpson, J. H., and Tett, P. B. (Eds) 1993. Understanding the North Sea system. Philosophical Transactions of the Royal Society of London, A. 343: 379–596.

Colebrook, J. M. 1975. The Continuous Plankton Recorder survey: automatic data processing methods. Bulletin of Marine Ecology, 8: 123–142.

Colebrook, J. M. 1986. Environmental influences on long-term variability in marine phytoplankton. Hydrobiologia, 142: 309–325.

Corten, A. 1990. Long-term trends in pelagic fish stocks of the North Sea and adjacent waters and their possible connection to hydrographic changes. Netherlands Journal of Sea Research, 25: 270–290.

Daan, N., Bromley, P. J., Hislop, J. R. G., and Nielsen, N. A. 1991. Ecology of North Sea fish. Netherlands Journal of Sea Research, 26: 343–386.

Dickson, R. R., Meincke, J., Malmberg, S-A., and Lee, A. J. 1988. The "Great Salinity Anomaly" in the northern Atlantic 1968–1982. Progress in Oceanography, 20: 103–151.

Eisma, D., and Kalf, J. 1987. Dispersal, concentration and deposition of suspended matter in the North Sea. Journal of the Geological Society of London, 144: 161–178.

Fransz, H. G., Colebrook, J. M., Gamble, J. C., and Krause, M. 1991. The zooplankton of the North Sea. Netherlands Journal of Sea Research, 28: 1–52.

Gekeler, J., and Radach, G. (Eds) 1994. NOWESP Research Data Base (NRDB) Technical Report. Institut für Meereskunde, Hamburg.

Gerlach, S. A. 1990. Nitrogen, phosphorus, plankton and oxygen deficiency in the German Bight and in Kiel Bay. Kieler Meeresforschungen, Sonderheft 7. 341 pp.

Hempel, G. 1978. Symposium on North Sea fish stocks – recent changes and their causes. Introduction and historical background. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 172: 5–9.

Hickel, W., Mangelsdorf, P., and Berg, J. 1993. The human impact in the German Bight: Eutrophication during three decades (1962–1991). Helgoländer Meeresuntersuchungen, 47: 243–263.

Hickel, W., Eickhoff, M., and Splindler, H. 1994. Changes in the German Bight pelagic environment during three decades. ICES CM 1994/E: 18. 8 pp.

Laane, R. W. P. M., Southward, A. J., Slinn, D. J., Allen, J., Groeneveld, G., and de Vries, A. 1996. Changes and causes of variability in salinity and dissolved inorganic phosphate in the Irish Sea, English Channel and in the Dutch coastal zone. ICES Journal of Marine Science, 53: 933–944.

Lenhart, H. J., Radach, G., Backhaus, J. O., and Pohlmann, T. 1995. Simulations of the North Sea circulation, its variability, and its implementation as hydrodynamical forcing in ERSEM. Netherlands Journal of Sea Research, 33: 271–299.

Lindeboom, H., van Raaphorst, W., Beukema, J., Cadée, G., and Swennen, C. 1994. (Sudden) changes in the North Sea and the Wadden Sea: oceanic influences underestimated? Deutsche Hydrographische Zeitschrift, Supplement 2, 87–100.

Mann, K. H., and Lazier, J. R. N. 1991. Dynamics of marine ecosystems. Blackwell Scientific Publications, Boston.

Otto, L., Zimmerman, J. T. F., Furnes, G. K., Mork, M., Saetre, R., and Becker, G. 1990. Review of the physical oceanography of the North Sea. Netherlands Journal of Sea Research, 26: 161–238.

Postma, H. 1981. Exchange of materials between the North Sea and the Wadden Sea. Marine Geology, 40: 199–213.

Schultz, H. 1995. Statistical analysis of time series data of the Helgoland station. NOWESP 2nd annual report: 125–128.

Sündermann, J. (Ed.) 1994. Circulation and contaminant fluxes in the North Sea. Springer, Berlin. 655 pp.

Svendsen, E., and Danielssen, D. 1995. Volume and nutrient transports in the northern North Sea and climate variability in the Skagerrak. NOWESP 2nd annual report: 201–210.

Taylor, A. H., Colebrook, J. M., Stephens, J. A., and Baker, N. G. 1992. Latitudinal displacements of the Gulf Stream and the abundance of plankton in the North-East Atlantic. Journal of the Marine Biological Association of the U.K., 72: 919–921.

Uhlig, G., and Sahling, G. 1990. Long-term studies on *Noctiluca scintillans* in the German Bight. Population dynamics and red tide phenomena 1968–1988. Netherlands Journal of Sea Research, 25: 101–112.

Van Alphen, J. S. L. J. 1990. A mud balance for Belgian–Dutch coastal waters between 1969 and 1986. Netherlands Journal of Sea Research, 25: 19–30.

Van Leussen, W., and Radach, G. (Eds) 1994. NOWESP Manual Statistical Analysis Techniques. NOWESP Project MAST II. Rijkswaterstaat, The Hague.

Visser, M., de Ruijter, W. P. M., and Postma, L. 1991. The distribution of suspended matter in the Dutch coastal zone. Netherlands Journal of Sea Research, 27: 127–143.

Walsh, J. J. 1988. On the nature of continental shelves. Academic Press, Inc. 520 pp.

Walsh, J. J. 1991. The North Sea Ecosystem. *In* Continental shelves, ecosystem of the world, 27, pp. 231–277. Ed. by H. Postma and J. J. Zijlstra. Elsevier, Amsterdam.