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Surface temperature and salinity time-series from the Rockall Channel, 1948-1992

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Summary

Observed mean monthly temperatures and salinities for a deep water area of the central Rockall Channel are tabulated for the years 1948-1992, with brief details of their collection and processing. Decadal monthly means and standard deviations are presented and briefly discussed, and a complete series of monthly salinity values from January 1948 to December 1992 is given, using interpolations from 30-year (1951-80) means to fill gaps in the observations. A similar series of monthly temperature means is given for January 1948 to September 1983 and November 1984 to December 1992. A brief discussion is given of the major features shown by the series and it is concluded that the salinity series is valuable in providing an adequate representation of decadal changes of salinity in the waters west of Britain and that the temperature series, though somewhat under-sampled, is not at variance with other surface temperature series in the north-eastern Atlantic.

1. INTRODUCTION

The establishment of Ocean Weather Stations in the Atlantic Ocean in 1946 prompted J.R. Lumby of the Fisheries Laboratory, Lowestoft to seek the co-operation of the UK Meteorological Office in extending the laboratory's surface temperature and salinity sampling network in the North Sea and English Channel to the waters west of Britain. Sampling on passage to and from the stations began in late 1947 and continues under Lowestoft auspices to the present day. Although the numbers of ships and stations have diminished over the years, samples are available from an area between the west of Scotland and Rockall in most months since January 1948. The data provided a time-series perspective of changes in the region for investigations in the Rockall Channel in the 1960s (Ellett and Martin, 1973), and have increased in value as the series has extended towards a 45-year span. In particular, these data first drew attention to the 'Great Salinity Anomaly' of the 1970s (Dickson *et al*., 1988), and continue to provide monitoring for north-eastern Atlantic variations (e.g., Ellett and Turrell, 1992).

The chosen area covers seven one-degree rectangles over the deep water of the Rockall Channel, with soundings mostly between 1000 and 2500 m (Figure 1). Between 1948 and 1975 these rectangles were crossed by UK Ocean Weather Ships steaming between their base in the River Clyde and stations '*India*' (north-west of Rockall) and '*Alfa*' (off East Greenland). Subsequently sampling became less intense as a single station, '*Lima*' (west of Rockall) was manned and the number of ships was reduced firstly in mid-1975 from four to two, and in 1982 to one. However, in 1973 the Dunstaffnage Marine Laboratory (DML) began a programme of investigations of the deep water west of Scotland which has supplemented the weather ship data with observations taken on research cruises usually between three and six times per year. Surface data have also become available from other European and American cruises during the past forty years.

2. SAMPLING PROCEDURES

2.1 Ocean Weather Ships, 1948-1956

Sampling from the first four UK weather ships (former 'Flower' class corvettes) was with the Lumby surface sampler (Lumby, 1927, 1928), in which thermometer and sample bottle were immersed together and towed for a minimum period of five minutes in the upper few metres of the sea. Thermometers were calibrated and corrected at Lowestoft and the salinity samples, collected in swing-stoppered bottles, were titrated at the Laboratory of the Government Chemist in London.

Salinity means and anomalies given in this report appear consistent with one another, but it may be noted here that a study by Turrell *et al.* (1993) of Government Chemist-determined salinity values of the Norwegian Sea Deep Water has suggested random errors in determination between batches of samples amounting to between +0.10 to -0.10 psu during the 1948-1961 period.

2.2 1956-1982

The four ships and their replacements ('Castle' class corvettes) were subsequently fitted with samplers in the engine room intakes which initially held a mercury-in-glass thermometer beside the sampling bottle, so that incoming water from a depth of about 4 m ran over the thermometer bulb and through the bottle. From 1961 the mercury thermometers were replaced in the sampler by distant-reading thermistor thermometers of the type described by Booker (1961). From mid-1961 salinity was determined at Lowestoft by thermostat salinometers, the first of the NIO type (Cox, 1963) and the second of a smaller but basically similar type designed by P. Booker. The thermostat instruments were superseded in 1965 by an Autolab inductively-coupled salinometer and in 1986 by a Guildline 'Autosal' conductivity salinometer.

2.3 1982 to date

Since February 1982 a single UK weather ship has been operated under contract by a commercial company. This was originally *MV STARELLA*, a large stern trawler, and since January 1986 has been the former Netherlands weather ship *CUMULUS*. Both ships sampled from engine room intakes at ca. 4 m depth. Salinity determination has continued to be carried out at Lowestoft, currently by 'Autosal' salinometer.

2.4 DML cruise data

The DML programme of physical oceanography in the Rockall Channel has centered upon a hydrographic section between the continental shelf-edge at 57°N, 9°W and Rockall (Figure 1). Surface salinity samples are collected at each station for calibration of conductivity-temperature-depth (CTD) profilers from a continuously-running clean seawater supply drawn from a depth of 4 m. The salinity of the samples was determined by Autolab inductively-coupled salinometers from 1973-1982 and by a Guildline 'Autosal' salinometer since 1982. Temperatures have been taken at the same depth from the calibrated CTD profiles, and in a few cases where salinity samples were missing, CTD salinity values have also been extracted. At other times surface salinity samples have been collected within the rectangles of interest from the clean seawater supply, but without accompanying temperature observations.

2.5 Other research ship data

Any surface temperature and salinity data noted in the area of interest have been extracted from published cruise reports and data lists, and have sometimes kindly been volunteered by Chief Scientists. This material forms a small, but often valuable, part of the data set, and is usually from water bottle or CTD sampling.

3. DATA PROCESSING

The simplest data processing methods have been used. Analysis of the series began in the early 1960s, when computers were a rarity and access to them difficult. All available surface observations

from a large area west of Britain were plotted on monthly charts within 1° x 1° rectangles, a process which served to detect position errors and check compatibility with adjacent observations. Rejection of dubious data has been done on subjective grounds, though with care. It could perhaps be argued that limits may have become more finely drawn for the later observations as a result of a thirty-year learning process. On the other hand, there was a greater quantity of data in the earlier years for comparison, and experience of other types of oceanographic data from the area has increased awareness of the occurrence of marked variations over short distances and time-scales in some circumstances.

Data for this time-series come from the seven deep water rectangles lying between 56°- 57°N, 9°- 13°W and 57°- 58°N, 10°- 13°W (Figure 1). Differences between the eastern-most and western-most rectangles were examined by Ellett and Martin (1973), who found for temperature that although summer monthly means over an 18-year period were cooler in the west by up to 0.46°K in August, in January to March differences were less at 0.15° to 0.21°K. However, coverage is not sufficient to obtain time-series of monthly means from each rectangle and consequently the observations within all nine rectangles have been meaned together. Since we are largely dealing with data collected on transits across the area there is some justification for this, but this spatial variation should be borne in mind as a possible factor influencing under-sampled monthly means. Temperature changes within the month will also reduce the precision of anomalies from mean values; Figure 2(a) shows the annual temperature cycle for the 30-year period, 1951-80. These means show a maximal temperature rise of 1.41°K between May and June, so that anomalies from observations at either ends of the months at this season could give unrepresentative values. Partly for these reasons, published work quoting this time-series has used only winter (January to March) temperature anomalies, when both errors are minimised, though all values are tabulated later in this report for completeness.

Ellett and Martin (1973) found that surface salinity means did not show a similar east to west variation in the 1948-1965 mean values, but in general had maximal values over the centre of the channel. Examination of the DML sections from 1975 to date shows considerable variability in surface maxima, although sub-surface maxima tend to be in the slope current over the slope zone. There seems little objection therefore to meaning salinity values across the complete set of rectangles, and the main bias in monthly means is that arising from the dates of sampling within the month. Figure 2(b) shows that in the 40-year mean cycle, month-to-month changes are again minimal in winter, but fall by 0.037 psu between June and July, and rise by 0.029 psu between October and November. For the remainder of the year month-to-month differences are small in comparison with interannual variations, and thus can be used with some confidence.

Mean monthly values for temperature obtained by these procedures are given in Table 1(a) for all but 55 months of the 45 years in the period January 1948 - December 1992. 12 of these missing values occur between September 1983 and November 1984 when weather ship tracks were to the south of the area, and DML cruises were restricted due to major ship repairs. Apart from these months, there are only two occasions when temperature data are missing for three consecutive months.

Mean monthly salinity values are available for all but 66 months over the total period of 540 months, and are given in Table 1(b). In this case 11 months' values are missing between September 1983 and November 1984. Observations are also missing for four consecutive months from October 1985 to January 1986, but outside these two periods gaps of missing data did not exceed two months.

3.1 Decadal and long-term means

Monthly temperature and salinity means for each of the four decades of the series are tabulated together with their standard deviations in Tables 2(a) and 2(b), and illustrated in Figures 3(a) and 3(b). The 30-year means for 1951-80 are also given: this latter period is widely used for meteorological purposes, and in particular for the mean monthly sea surface temperature distributions of the *Global Ocean Surface Temperature Atlas* (GOSTA, 1990), and it has been thought useful to link the present series to these comprehensive means.

Most earlier discussion of the data (e.g. Ellett, 1983) has been with respect to means for the decade 1961-70, the period recommended for reports to the (now discontinued) *Annales Biologiques* of the International Council for the Exploration of the Sea (ICES), but this can be recognised from Figure 3(b) as a notably more saline decade than those preceding and following, and the 30-year 1951-80 period has therefore been adopted for recent processing.

3.2 Completing the series : interpolations for missing data

The value of the data set from the Rockall Channel in signalling significant changes in the oceanic waters west of Britain was demonstrated when consistently falling salinity values in the 1970s (Ellett, 1978) drew attention to the phenomenon subsequently named the Great Salinity Anomaly by Dickson *et al.* (1988). In recent years it has contributed to investigations of high salinity in European seas during the early 1990s (Ellett and Turrell, 1992). However, for these purposes and for possible future modelling input the missing 12% of monthly means need to be estimated. Again, it has been felt that the limited quantity of data warranted the simplest of treatment, and the following method has been adopted to fill gaps in the series.

For all available monthly means, temperature and salinity anomalies from mean monthly values have been obtained, in the present case from the 1950-81 monthly means. A linear increase or decrease of the anomaly has been assumed across the missing months (normally not more than two) and these interpolated figures have been added arithmetically to the monthly means to obtain the missing values. This method therefore retains the seasonal component of the mean and adds an estimate of the anomaly to it, and around the months of seasonal maxima and minima is slightly preferable to a direct interpolation across observed values.

Tables 3(a) and 3(b) have been completed by this method. Interpolated values are shown by shading. Temperature values have been omitted where interpolation would have been spurious from September 1983 to October 1984, except for the observations taken in June 1984. During the same period salinity values have been interpolated over two intervals of four months, and there is one further example during October 1985 to January 1986. It is arguable that this is justified by the relatively small range of salinity variation and the interest in providing a complete series, but their origin should be borne in mind.

3.3 Principal features of the time-series

Although the main aim of this report is to present and document the time-series in a convenient form for fellow workers, attention may be drawn to the major features of the series. This is most clearly effected by reference to the anomalies from the 1951-80 means, which are given in Tables 4(a) and 4(b).

Figure 4 presents the mean winter (January - March) temperature and salinity anomalies from the 1951-80 mean monthly values from 1948 to 1992. There are two reasons for regarding the anomalies from this season as the most reliable of the series. The first, mentioned above, is that month-to-month changes of the seasonal cycle are at a minimum and interpolations for missing values are less likely to introduce significant errors than in other months, and the second is that under the influence of heat losses and strong winds the upper waters of the Rockall Channel are mixed to depths frequently exceeding 400 m (Ellett *et al*., 1986), so that observations taken at 4 m depth are more truly representative of oceanic conditions than at other seasons.

In view of the reservations concerning under-sampling in the temperature means, Figure 4 also shows surface temperature anomalies from the GOSTA data set for the 5° x 5° rectangle 55° - 60°N, 10° - 15°W which includes our Rockall Channel area. While this set also includes temperatures from the weather ships on passage, the series is more comprehensive and includes all available data from voluntary observing merchant ships. Mean monthly temperatures for the 5° rectangle are lower than those for the seven 1° rectangles (Figure 2(a)) because of the influence of data from the northern parts of the larger rectangle, but it can be seen that there is close agreement between most of the winter anomalies; indeed, the only major difference is a notably higher value from the Rockall Channel series in one winter, 1981. Thus although individual temperature values should be treated with caution, comparison with the GOSTA data suggests that the winter anomalies correctly reflect the general character of the temperature changes during the 45-year period. These are; firstly a general warming to a maximum in the later 1950s, then a period with temperatures close to the 1951-80 average during the 1960s, and finally a cool spell from the early 1970s until the late 1980s except for a few ‘normal’ years around 1980. Currently, conditions seem to be remaining cool.

Figure 4 shows that salinity changes may be said to have developed consistently, and in general there are less reservations (in contrast to the temperature values) about the representativeness of monthly values. Only in summer (June to August) and late autumn (October to December) are month-to-month differences between the means of a magnitude large enough to seriously bias anomalies from undersampled months. The winter series of Figure 4 begins with generally increasing salinity levels from 1950 until 1968, followed by a low-salinity period in the mid-1970s during the transit of the Great Salinity Anomaly (Dickson *et al*., 1988). The 1980s were characterised by slightly above to slightly below average values, and the early 1990s by relatively high values which have been noted elsewhere in European waters (Heath *et al*., 1991; Ellett and Turrell, 1992; Becker and Dooley, in press).

The unique value of the salinity series in monitoring significant North-east Atlantic events in some detail may be demonstrated by plots of monthly salinity anomalies from the high-salinity period of the late 1960s to the aftermath of the Great Salinity Anomaly in the late 1970s (Figure 5). This shows a rather gradual decline after the maximal values of 1965-67 until 1972, when salinity fell rapidly in early summer but recovered briefly in the following autumn, before three years of falling anomalies which reached a minimum in October 1975. The following recovery was initially rapid, but from spring 1976 until the end of 1978 low anomalies persisted, mean 1951-80 values only being attained in late 1979.

4. CONCLUSIONS

These time-series offer valuable indices to the major variations of temperature and salinity in oceanic waters to the west of the British Isles over the past 45 years. Although the data are sparser than

could ideally be wished, the acquisition of observations in all but 12% of the 540 months is a notable contribution to long-term oceanographic studies. The irregular distribution of temperature observations within a particular month is liable to bias comparisons with mean values at seasons other than the winter when variation within the month is small, and in this season there is good agreement with more complete sampling from a surrounding area. Salinity is only affected by this factor in summer and late autumn, though winter values have additional oceanographic significance because of the deep mixing which allows surface observations represent a much thicker surface layer at this season.

Acknowledgements

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The reference to proprietary products in this report should not be construed as an official endorsement of these products, nor is any criticism implied of similar products which have not been mentioned.

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Table 1(a). Observed mean monthly surface temperature (°C)(with number of observations per month) in the central Rockall Channel, 1948-1992

Year	Jan	No.	Feb	No.	Mar	No.	Apr	No.	May	No.	Jun	No.	Jul	No.	Aug	No.	Sep	No.	Oct	No.	Nov	No.	Dec	No.	Year
1948	9.90	2			9.60	1	9.67	3	10.17	7	11.98	4	12.73	9	13.40	6	12.23	9	11.30	1	9.88	10	10.28	5	1948
1949	9.79	11	9.80	7	9.19	7	9.58	13	10.44	5	12.23	6	14.51	11	13.84	8	14.28	5	13.30	11	11.31	7	9.72	12	1949
1950	9.35	8	9.56	8	9.73	13	9.92	4			11.70	4	13.05	2	14.07	3					10.67	3			1950
1951	9.52	4	9.44	7	9.35	2	9.22	12			12.64	5					14.40	3			11.62	8	10.98	4	1951
1952					9.34	5	10.18	5	10.75	4	11.35	6	13.00	6	14.92	11	12.67	14	11.89	8	10.78	9	10.50	1	1952
1953	10.01	9	9.87	3	10.20	1	9.65	2	10.70	9	12.30	9			14.28	9	14.07	3	12.52	5			10.40	1	1953
1954	10.25	2	9.60	3	9.50	1	9.80	1	10.40	3	12.50	1	12.76	14	13.41	20	13.22	8	11.80	18	10.44	7	9.95	4	1954
1955	9.28	6	9.70	6	9.70	3	10.19	7	10.73	7	12.55	4	14.33	12	15.73	14			12.42	5	11.68	17	10.93	10	1955
1956	10.06	8	9.94	8	9.95	4	10.30	5	10.43	11	11.37	10	13.28	17	13.10	4	12.77	9	12.19	8	11.37	11	10.69	8	1956
1957	10.70	17	10.54	11	10.27	6	10.63	9	11.19	8	12.13	19	14.10	9	14.66	14	13.99	7	11.78	6	10.99	13	10.96	7	1957
1958	10.51	16	10.20	9	10.00	9	9.62	4	10.92	9	12.25	6	14.35	6	14.71	7	14.99	11	12.67	9	11.90	13	11.05	4	1958
1959	10.61	14	10.00	4	10.08	5	10.37	22	11.75	9	12.72	8	14.01	18	14.25	4	13.32	6	12.85	21	12.05	8	10.91	7	1959
1960	11.26	9	10.44	14			10.52	12	11.96	19	13.01	18	14.82	8	15.16	8	14.11	17	12.81	8	11.59	9	10.62	16	1960
1961	10.31	19	9.99	8	10.07	3	9.86	11	10.86	27	11.81	9	12.57	21	13.24	16	13.16	5	12.16	11	11.05	12	10.08	14	1961
1962			9.49	14	9.45	6	10.12	9	10.63	12	11.46	11	12.44	8	13.52	6	12.68	6	12.15	8	10.88	9	10.09	16	1962
1963	9.63	13	9.36	7	9.33	17	9.70	7			12.36	8	12.91	17	13.28	14	12.49	21	11.39	15	10.98	8	10.16	5	1963
1964	9.96	13	9.99	11	9.88	16	9.98	13	10.63	13	12.54	9	12.76	14	13.63	6	12.84	11	12.20	15	11.32	5	10.35	11	1964
1965	9.75	9	9.55	8	9.40	9	9.74	18	10.84	9	12.77	11			13.73	12	12.80	6	12.39	7	11.18	18	10.30	1	1965
1966	9.80	2	9.85	6	9.60	13	9.68	6	10.31	7	12.18	11	13.66	18	14.14	5	13.22	5	12.50	11	10.58	5	9.78	5	1966
1967	10.05	18	9.80	2			9.83	7	10.43	7	12.05	10	13.03	9	13.26	9	13.00	9	11.42	5	10.31	13	10.12	6	1967
1968	9.89	10	9.80	14	9.23	3	10.30	2	10.67	7	12.34	5	13.42	6	15.82	8	14.26	10	12.18	6	11.28	8	10.63	6	1968
1969	10.28	6	10.06	8	9.86	8	10.02	6	10.71	9	12.77	10	12.46	9	13.80	10	13.48	6	11.98	4	10.80	2	10.21	16	1969
1970	10.02	4	9.63	6	9.70	13	9.86	10			12.80	3	12.17	9	13.62	15	12.88	6	11.82	6	10.81	9	10.25	2	1970
1971	10.10	8	10.18	11	10.00	20	10.00	3	10.75	12	11.71	8	12.78	12	13.68	4	13.87	6	12.87	9	11.36	7	10.65	2	1971
1972	10.20	3	9.91	9	9.84	5	9.70	5	10.00	5	10.85	11	12.73	3	12.64	5	12.87	9	12.23	10	10.76	3	10.20	3	1972
1973	9.89	8	9.36	7	9.57	6	9.37	6	10.39	14	11.43	10	12.61	8	13.40	17	13.08	11	11.55	11	10.65	6	10.28	9	1973
1974	9.89	7	9.10	4	9.48	5	10.62	8	10.94	8	11.35	8	13.06	7	13.72	12	12.80	6	11.20	6	10.51	8			1974
1975	9.60	2	9.45	6	9.42	15	9.84	9	10.35	6	11.60	5	13.73	6	14.43	12	13.70	2	12.25	2	11.77	3	10.60	1	1975
1976	9.93	3	9.82	5	9.67	4	9.64	5	10.50	3	12.18	5	13.63	3	13.70	10	14.70	2	12.69	8	11.33	3	10.16	12	1976
1977	10.05	4	9.80	1	9.36	7	9.32	14	10.70	2	12.37	3	12.81	13	14.58	15	12.83	3	12.20	3	10.54	5	10.10	2	1977
1978	9.84	5	9.28	20	9.60	3	9.24	22	10.28	4	11.66	14	12.75	2	13.32	17	13.24	11	12.12	4	11.30	9	10.97	7	1978
1979	10.10	3	9.88	11	9.68	5	9.38	6	9.70	15	11.52	4	13.30	4	13.50	3	12.54	6	12.07	3	10.93	3	10.62	5	1979
1980	10.10	3	9.94	5	9.43	20	10.30	2	10.60	15	11.85	4	12.73	3	14.00	3	13.18	3	11.83	3	11.23	3	10.65	4	1980
1981	10.42	9	10.30	3	10.50	2	10.34	10	11.35	6	12.70	2	12.88	4	14.10	4	14.27	3	11.40	11	10.94	5	10.70	1	1981
1982			9.85	29			10.28	11	9.79	21					13.75	4			11.72	4	11.35	2	10.75	2	1982
1983							9.60	2	10.48	18					13.59	14	12.70	1							1983
1984											11.82	11									10.76	8			1984
1985	9.55	6	10.10	1			9.90	1	9.87	13			13.55	2	13.45	14	12.40	1					10.40	1	1985
1986	10.00	1	10.10	1	9.45	10	10.05	2	10.00	3			13.15	2	13.20	3	12.65	2	11.60	2	10.10	2	9.70	2	1986
1987	9.45	8	9.40	2	9.45	2	9.78	15	10.05	2	12.48	4					13.48	5	11.45	2	11.15	2	10.45	2	1987
1988	9.95	2	9.50	1	9.43	5	9.55	2	10.33	6	12.22	8			13.40	2	13.15	2	11.98	6	11.40	2	10.70	4	1988
1989	9.70	14	10.10	3	9.65	2	9.60	1	9.86	14	12.20	1			14.00	12	12.65	2	11.50	1	10.93	12	11.05	2	1989
1990	10.45	2	9.58	4	9.67	3	9.57	3	12.30	1	12.88	13	13.20	1	13.63	6	13.76	16	12.00	2	11.03	3			1990
1991	10.20	3	9.36	15	9.66	5	9.77	6	10.57	3			13.67	22	13.80	1	14.05	4	11.63	3	10.75	4	10.50	2	1991
1992							9.30	1	9.83	10			12.90	3	13.40	2	11.70	14	12.21	4	10.75	2	10.12	4	1992

Table 1(b). Observed mean monthly surface salinity (with number of observations per month) in the central Rockall Channel, 1948-1992

Year	Jan	No.	Feb	No.	Mar	No.	Apr	No.	May	No.	Jun	No.	Jul	No.	Aug	No.	Sep	No.	Oct	No.	Nov	No.	Dec	No.	Year
1948	35.350	2					35.405	6	35.409	7	35.375	4	35.363	7	35.338	6	35.288	8	35.327	3	35.315	10	35.335	3	1948
1949	35.384	7	35.343	7	35.340	7	35.335	12	35.318	5	35.362	6	35.375	11	35.310	8	35.270	4	35.212	10	35.327	6	35.305	11	1949
1950	35.263	7	35.356	5	35.382	12	35.342	4			35.240	4	35.225	2	35.230	3					35.290	2			1950
1951	35.375	4	35.330	6	35.360	1	35.352	12			35.396	4					35.430	1			35.402	8	35.405	4	1951
1952					35.360	3	35.392	5	35.410	4	35.355	6	35.422	4	35.363	11	35.384	14	35.375	6	35.442	8	35.370	1	1952
1953	35.380	8	35.413	3			35.360	2	35.380	9	35.389	8			35.332	9	35.235	2	35.222	5			35.350	1	1953
1954	35.430	2	35.420	3	35.370	1	35.350	1	35.387	3	35.420	1	35.415	13	35.372	19	35.321	8	35.322	17	35.286	7	35.314	4	1954
1955	35.345	6	35.402	6	35.380	3	35.386	10	35.409	8	35.362	4	35.296	12	35.293	14			35.362	4	35.334	17	35.376	10	1955
1956	35.388	6	35.435	6	35.402	3	35.430	5	35.469	9	35.440	10	35.370	17	35.345	4	35.388	9	35.398	8	35.427	11	35.424	8	1956
1957	35.436	17	35.446	11	35.420	3	35.452	9	35.458	8	35.402	17	35.385	8	35.396	14	35.381	7	35.360	6	35.384	11	35.410	7	1957
1958	35.425	15	35.385	8	35.381	9	35.430	2	35.431	7	35.418	6	35.355	4	35.412	7	35.361	15	35.431	7	35.427	12	35.438	4	1958
1959	35.451	10	35.445	2	35.450	4	35.427	21	35.474	11	35.436	7	35.409	18	35.317	4	35.330	4	35.358	14	35.398	8	35.415	6	1959
1960	35.431	9	35.386	14			35.443	10	35.451	11	35.423	14	35.324	8	35.385	8	35.358	16	35.397	6	35.398	9	35.422	16	1960
1961	35.421	16	35.407	6	35.437	3	35.396	10	35.398	24	35.410	9	35.397	18	35.339	16	35.343	3	35.324	11	35.347	12	35.386	14	1961
1962			35.416	13	35.414	5	35.332	8	35.424	7	35.359	14	35.292	8	35.212	4	35.288	5	35.230	9	35.264	7	35.304	16	1962
1963	35.408	11	35.401	7	35.409	15	35.416	7			35.382	8	35.380	17	35.330	14	35.320	20	35.308	13	35.313	7	35.376	5	1963
1964	35.395	13	35.407	11	35.423	16	35.410	12	35.391	11	35.373	9	35.369	12	35.340	6	35.290	11	35.308	14	35.325	4	35.372	10	1964
1965	35.382	8	35.389	8	35.400	9	35.411	15	35.433	10	35.357	9			35.398	12	35.394	5	35.420	7	35.422	17	35.450	1	1965
1966	35.420	2	35.453	6	35.439	13	35.475	6	35.454	7	35.442	11	35.414	17	35.425	4	35.424	5	35.449	11	35.460	5	35.434	5	1966
1967	35.460	8	35.450	2			35.451	7	35.461	7	35.462	9	35.450	9	35.417	9	35.394	9	35.422	5	35.430	13	35.427	6	1967
1968	35.435	18	35.447	14	35.475	3	35.425	2	35.396	7	35.404	5	35.385	6	35.378	8	35.339	9	35.311	6	35.325	8	35.345	6	1968
1969	35.408	6	35.415	8	35.407	7	35.435	6	35.404	8	35.423	9	35.403	9	35.331	10	35.323	6	35.335	4	35.415	2	35.403	13	1969
1970	35.417	3	35.432	5	35.427	9	35.438	5			35.410	1	35.388	9	35.371	13	35.353	6	35.375	6	35.390	9	35.420	2	1970
1971	35.432	9	35.409	11	35.415	20	35.418	8	35.412	12	35.426	8	35.380	12	35.385	4	35.360	7	35.350	9	35.369	7	35.440	1	1971
1972	35.395	4	35.406	10	35.428	5	35.403	4	35.352	5	35.325	11	35.325	4	35.290	5	35.354	9	35.343	10	35.389	9	35.387	3	1972
1973	35.407	9	35.403	7	35.347	6	35.371	6	35.390	12	35.389	10	35.336	9	35.310	17	35.334	8	35.347	11	35.330	6	35.349	11	1973
1974	35.361	7	35.325	4	35.358	8	35.353	7	35.338	4	35.311	8	35.294	5	35.268	12	35.227	6	35.237	5	35.268	8			1974
1975	35.312	2	35.338	5	35.332	13	35.308	8	35.323	6	35.323	5	35.264	18	35.234	12	35.182	2	35.130	2	35.194	15			1975
1976	35.273	3	35.321	5	35.309	3	35.310	19	35.305	13	35.343	3	35.285	2	35.225	10	35.308	2	35.285	4	35.307	3	35.329	21	1976
1977	35.334	3	35.294	1	35.323	12	35.336	14	35.356	2			35.305	12	35.281	17			35.264	2	35.337	1	35.370	2	1977
1978	35.342	5	35.321	20	35.342	3	35.340	17	35.331	3	35.321	14	35.310	2	35.268	6	35.229	8	35.312	4	35.274	10	35.298	3	1978
1979	35.342	3	35.369	9	35.373	5	35.370	5	35.367	9	35.409	4	35.333	3	35.347	3	35.338	5	35.346	2	35.329	9	35.383	5	1979
1980	35.397	2	35.383	6	35.377	24	35.409	9	35.423	16	35.460	3	35.425	3	35.384	3	35.335	3	35.348	2	35.433	3	35.428	4	1980
1981	35.400	9	35.418	3	35.376	2	35.360	10	35.357	5	35.340	2	35.279	3	35.273	4	35.287	3	35.309	10	35.364	3	35.391	1	1981
1982			35.409	28			35.402	8	35.403	23					35.391	4			35.383	5			35.437	2	1982
1983			35.389	9			35.414	2	35.416	18					35.366	14	35.392	1							1983
1984	35.426	13									35.401	12									35.403	8			1984
1985	35.394	9	35.374	1			35.387	1	35.384	21			35.278	2	35.299	19	35.318	1							1985
1986			35.408	1	35.379	11	35.394	2	35.362	3			35.310	1	35.293	3	35.342	2	35.306	2	35.353	2	35.353	1	1986
1987	35.358	8	35.356	2	35.398	2	35.385	23	35.368	2	35.370	4					35.283	5	35.384	1	35.362	1			1987
1988	35.371	2	35.382	1	35.371	3	35.368	2	35.340	6	35.353	10			35.276	2	35.294	2	35.309	6			35.391	4	1988
1989	35.336	14	35.400	3	35.413	2	35.391	1	35.377	18	35.439	1			35.307	16	35.364	2	35.408	1	35.432	12	35.445	2	1989
1990	35.484	2	35.403	3	35.430	7	35.436	3	35.447	1	35.381	17			35.325	10	35.315	14			35.447	1			1990
1991	35.437	3	35.400	22	35.415	7	35.406	6	35.432	3			35.372	22	35.341	1	35.350	3	35.355	3	35.380	4	35.413	3	1991
1992					35.435	4	35.389	1	35.402	6			35.341	3	35.230	1	35.213	13	35.210	4	35.278	2	35.341	2	1992

Table 2(a). Decadal and 30-year mean monthly temperature and standard deviations

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Years
1951-60	10.24	9.97	9.82	10.05	10.98	12.28	13.83	14.47	13.73	12.33	11.38	10.70	1951-60
s.d.	0.60	0.37	0.36	0.45	0.55	0.55	0.73	0.82	0.78	0.43	0.54	0.34	s.d.
no. yrs.	9	9	9	10	9	10	8	9	9	9	9	10	no. yrs.
1961-70	9.97	9.75	9.61	9.91	10.64	12.31	12.82	13.80	13.08	12.02	10.92	10.20	1961-70
s.d.	0.23	0.24	0.28	0.20	0.19	0.44	0.48	0.76	0.50	0.37	0.32	0.22	s.d.
no. yrs.	9	10	9	10	8	10	9	10	10	10	10	10	no. yrs.
1971-80	9.97	9.67	9.61	9.74	10.42	11.65	13.01	13.70	13.28	12.10	11.04	10.47	1971-80
s.d.	0.18	0.35	0.20	0.46	0.37	0.43	0.40	0.56	0.64	0.49	0.42	0.30	s.d.
no. yrs.	10	10	10	10	10	10	10	10	10	10	10	9	no. yrs.
1981-90	9.93	9.87	9.69	9.85	10.45	12.38	13.20	13.64	13.13	11.66	10.96	10.54	1981-90
s.d.	0.40	0.34	0.41	0.31	0.85	0.38	0.28	0.30	0.65	0.25	0.41	0.43	s.d.
no. yrs.	7	8	6	9	9	6	4	8	8	7	8	7	no. yrs.
1951-80	10.06	9.79	9.68	9.90	10.67	12.08	13.19	13.97	13.35	12.14	11.10	10.45	1951-80
s.d.	0.39	0.33	0.29	0.40	0.46	0.55	0.68	0.77	0.68	0.44	0.46	0.35	s.d.
no. yrs.	28	29	28	30	27	30	27	29	29	29	29	29	no. yrs.

Table 2(b). Decadal and 30-year mean monthly salinity and standard deviations

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Years
1951-60	35.407	35.407	35.390	35.402	35.430	35.404	35.372	35.357	35.354	35.358	35.389	35.392	1951-60
s.d.	0.036	0.037	0.032	0.039	0.035	0.029	0.045	0.039	0.055	0.060	0.050	0.039	s.d.
no.yrs.	9	9	8	10	9	10	8	9	9	9	9	10	no. yrs.
1961-70	35.416	35.422	35.426	35.419	35.420	35.402	35.386	35.354	35.347	35.348	35.369	35.392	1961-70
s.d.	0.023	0.022	0.023	0.038	0.027	0.035	0.043	0.061	0.045	0.067	0.063	0.045	s.d.
no. yrs.	9	10	9	10	8	10	9	10	10	10	10	10	no. yrs
1971-80	35.360	35.357	35.360	35.362	35.360	35.367	35.326	35.299	35.296	35.296	35.323	35.373	1971-80
s.d.	0.049	0.042	0.039	0.039	0.039	0.055	0.047	0.057	0.066	0.071	0.068	0.048	s.d.
no. yrs.	10	10	10	10	10	9	10	10	9	10	10	8	no. yrs.
1981-90	35.396	35.393	35.395	35.393	35.384	35.381	35.289	35.316	35.324	35.350	35.394	35.403	1981-90
s.d.	0.049	0.020	0.023	0.023	0.033	0.036	0.018	0.042	0.039	0.047	0.040	0.038	s.d.
no. yrs.	7	9	6	9	9	6	3	8	8	6	6	5	no. yrs.
1951-80	35.393	35.395	35.391	35.394	35.401	35.392	35.360	35.336	35.333	35.333	35.359	35.387	1951-80
s.d.	0.044	0.043	0.041	0.044	0.046	0.043	0.052	0.059	0.059	0.069	0.064	0.042	s.d.
no. yrs.	28	29	27	30	27	29	27	29	28	29	29	28	no. yrs.

Table 3(a). Monthly mean surface temperature series with interpolations (shaded values), 1948-1992

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1948	9.90	9.67	9.60	9.67	10.17	11.98	12.73	13.40	12.23	11.30	9.88	10.28	1948
1949	9.79	9.80	9.19	9.58	10.44	11.15	14.51	13.84	14.28	13.30	11.31	9.72	1949
1950	9.35	9.56	9.73	9.92	10.49	11.70	13.05	14.07	13.28	11.89	10.67	9.97	1950
1951	9.52	9.44	9.35	9.22	10.61	12.64	13.91	14.88	14.40	12.92	11.62	10.98	1951
1952	10.30	9.74	9.34	10.18	10.75	11.35	13.00	14.92	12.67	11.89	10.78	10.50	1952
1953	10.01	9.87	10.20	9.65	10.70	12.30	13.45	14.28	14.07	12.52	11.27	10.40	1953
1954	10.25	9.60	9.50	9.80	10.40	12.50	12.76	13.41	13.22	11.80	10.44	9.95	1954
1955	9.28	9.70	9.70	10.19	10.73	12.55	14.33	15.73	14.37	12.42	11.68	10.93	1955
1956	10.06	9.94	9.95	10.30	10.43	11.37	13.28	13.10	12.77	12.19	11.37	10.69	1956
1957	10.70	10.54	10.27	10.63	11.19	12.13	14.10	14.66	13.99	11.78	10.99	10.96	1957
1958	10.51	10.20	10.00	9.62	10.92	12.25	14.35	14.71	14.99	12.67	11.90	11.05	1958
1959	10.61	10.00	10.08	10.37	11.75	12.72	14.01	14.25	13.32	12.85	12.05	10.91	1959
1960	11.26	10.44	10.32	10.52	11.96	13.01	14.82	15.16	14.11	12.81	11.59	10.62	1960
1961	10.31	9.99	10.07	9.86	10.86	11.81	12.57	13.24	13.16	12.16	11.05	10.08	1961
1962	9.72	9.49	9.45	10.12	10.63	11.46	12.44	13.52	12.68	12.15	10.88	10.09	1962
1963	9.63	9.36	9.33	9.70	10.71	12.36	12.91	13.28	12.49	11.39	10.98	10.16	1963
1964	9.96	9.99	9.88	9.98	10.63	12.54	12.76	13.63	12.84	12.20	11.32	10.35	1964
1965	9.75	9.55	9.40	9.74	10.84	12.77	13.42	13.73	12.80	12.39	11.18	10.30	1965
1966	9.80	9.85	9.60	9.68	10.31	12.18	13.66	14.14	13.22	12.50	10.58	9.78	1966
1967	10.05	9.80	9.65	9.83	10.43	12.05	13.03	13.26	13.00	11.42	10.31	10.12	1967
1968	9.89	9.80	9.23	10.30	10.67	12.34	13.42	15.82	14.26	12.18	11.28	10.63	1968
1969	10.28	10.06	9.86	10.02	10.71	12.77	12.46	13.80	13.48	11.98	10.80	10.21	1969
1970	10.02	9.63	9.70	9.86	11.01	12.80	12.17	13.62	12.88	11.82	10.81	10.25	1970
1971	10.10	10.18	10.00	10.00	10.75	11.71	12.78	13.68	13.87	12.87	11.36	10.65	1971
1972	10.20	9.91	9.84	9.70	10.00	10.85	12.73	12.64	12.87	12.23	10.76	10.20	1972
1973	9.89	9.36	9.57	9.37	10.39	11.43	12.61	13.40	13.08	11.55	10.65	10.28	1973
1974	9.89	9.10	9.48	10.62	10.94	11.35	13.06	13.72	12.80	11.20	10.51	9.93	1974
1975	9.60	9.45	9.42	9.84	10.35	11.60	13.73	14.43	13.70	12.25	11.77	10.60	1975
1976	9.93	9.82	9.67	9.64	10.50	12.18	13.63	13.70	14.70	12.69	11.33	10.16	1976
1977	10.05	9.80	9.36	9.32	10.70	12.37	12.81	14.58	12.83	12.20	10.54	10.10	1977
1978	9.84	9.28	9.60	9.24	10.28	11.66	12.75	13.32	13.24	12.12	11.30	10.97	1978
1979	10.10	9.88	9.68	9.38	9.70	11.52	13.30	13.50	12.54	12.07	10.93	10.62	1979
1980	10.10	9.94	9.43	10.30	10.60	11.85	12.73	14.00	13.18	11.83	11.23	10.65	1980
1981	10.42	10.30	10.50	10.34	11.35	12.70	12.88	14.10	14.27	11.40	10.94	10.70	1981
1982	10.22	9.85	9.90	10.28	9.79	11.42	12.75	13.75	13.03	11.72	11.35	10.75	1982
1983	10.21	9.79	9.53	9.60	10.48	11.83	12.87	13.59	12.70				1983
1984						11.82					10.76	10.03	1984
1985	9.55	10.10	9.83	9.90	9.87	11.86	13.55	13.45	12.40	11.49	10.75	10.40	1985
1986	10.00	10.10	9.45	10.05	10.00	11.72	13.15	13.20	12.65	11.60	10.10	9.70	1986
1987	9.45	9.40	9.45	9.78	10.05	12.48	13.50	14.19	13.48	11.45	11.15	10.45	1987
1988	9.95	9.50	9.43	9.55	10.33	12.22	12.97	13.40	13.15	11.98	11.40	10.70	1988
1989	9.70	10.10	9.65	9.60	9.86	12.20	13.27	14.00	12.65	11.50	10.93	11.05	1989
1990	10.45	9.58	9.67	9.57	12.30	12.88	13.20	13.63	13.76	12.00	11.03	10.49	1990
1991	10.20	9.36	9.66	9.77	10.57	12.27	13.67	13.80	14.05	11.63	10.75	10.50	1991
1992	9.95	9.52	9.24	9.30	9.83	11.52	12.90	13.40	11.70	12.21	10.75	10.12	1992

Table 3(b). Monthly mean surface salinity series with interpolations (shaded values), 1948-1992

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1948	35.350	35.370	35.384	35.405	35.409	35.375	35.363	35.338	35.288	35.327	35.315	35.335	1948
1949	35.384	35.343	35.340	35.335	35.318	35.362	35.375	35.310	35.270	35.212	35.327	35.305	1949
1950	35.263	35.356	35.382	35.342	35.299	35.240	35.225	35.230	35.239	35.252	35.290	35.343	1950
1951	35.375	35.330	35.360	35.352	35.382	35.396	35.395	35.402	35.430	35.403	35.402	35.405	1951
1952	35.395	35.380	35.360	35.392	35.410	35.355	35.422	35.363	35.384	35.375	35.442	35.370	1952
1953	35.380	35.413	35.383	35.360	35.380	35.389	35.356	35.332	35.235	35.222	35.285	35.350	1953
1954	35.430	35.420	35.370	35.350	35.387	35.420	35.415	35.372	35.321	35.322	35.286	35.314	1954
1955	35.345	35.402	35.380	35.386	35.409	35.362	35.296	35.293	35.326	35.362	35.334	35.376	1955
1956	35.388	35.435	35.402	35.430	35.469	35.440	35.370	35.345	35.388	35.398	35.427	35.424	1956
1957	35.436	35.446	35.420	35.452	35.458	35.402	35.385	35.396	35.381	35.360	35.384	35.410	1957
1958	35.425	35.385	35.381	35.430	35.431	35.418	35.355	35.412	35.361	35.431	35.427	35.438	1958
1959	35.451	35.445	35.450	35.427	35.474	35.436	35.409	35.317	35.330	35.358	35.398	35.415	1959
1960	35.431	35.386	35.411	35.443	35.451	35.423	35.324	35.385	35.358	35.397	35.398	35.422	1960
1961	35.421	35.407	35.437	35.396	35.398	35.410	35.397	35.339	35.343	35.324	35.347	35.386	1961
1962	35.403	35.416	35.414	35.332	35.424	35.359	35.292	35.212	35.288	35.230	35.264	35.304	1962
1963	35.408	35.401	35.409	35.416	35.407	35.382	35.380	35.330	35.320	35.308	35.313	35.376	1963
1964	35.395	35.407	35.423	35.410	35.391	35.373	35.369	35.340	35.290	35.308	35.325	35.372	1964
1965	35.382	35.389	35.400	35.411	35.433	35.357	35.373	35.398	35.394	35.420	35.422	35.450	1965
1966	35.420	35.453	35.439	35.475	35.454	35.442	35.414	35.425	35.424	35.449	35.460	35.434	1966
1967	35.460	35.450	35.447	35.451	35.461	35.462	35.450	35.417	35.394	35.422	35.430	35.427	1967
1968	35.435	35.447	35.475	35.425	35.396	35.404	35.385	35.378	35.339	35.311	35.325	35.345	1968
1969	35.408	35.415	35.407	35.435	35.404	35.423	35.403	35.331	35.323	35.335	35.415	35.403	1969
1970	35.417	35.432	35.427	35.438	35.432	35.410	35.388	35.371	35.353	35.375	35.390	35.420	1970
1971	35.432	35.409	35.415	35.418	35.412	35.426	35.380	35.385	35.360	35.350	35.369	35.440	1971
1972	35.395	35.406	35.428	35.403	35.352	35.325	35.325	35.290	35.354	35.343	35.389	35.387	1972
1973	35.407	35.403	35.347	35.371	35.390	35.389	35.336	35.310	35.334	35.347	35.330	35.349	1973
1974	35.361	35.325	35.358	35.353	35.338	35.311	35.294	35.268	35.227	35.237	35.268	35.301	1974
1975	35.312	35.338	35.332	35.308	35.323	35.323	35.264	35.234	35.182	35.130	35.194	35.245	1975
1976	35.273	35.321	35.309	35.310	35.305	35.343	35.285	35.225	35.308	35.285	35.307	35.329	1976
1977	35.334	35.294	35.323	35.336	35.356	35.342	35.305	35.281	35.271	35.264	35.337	35.370	1977
1978	35.342	35.321	35.342	35.340	35.331	35.321	35.310	35.268	35.229	35.312	35.274	35.298	1978
1979	35.342	35.369	35.373	35.370	35.367	35.409	35.333	35.347	35.338	35.346	35.329	35.383	1979
1980	35.397	35.383	35.377	35.409	35.423	35.460	35.425	35.384	35.335	35.348	35.433	35.428	1980
1981	35.400	35.418	35.376	35.360	35.357	35.340	35.279	35.273	35.287	35.309	35.364	35.391	1981
1982	35.402	35.409	35.402	35.402	35.403	35.412	35.397	35.391	35.385	35.383	35.409	35.437	1982
1983	35.415	35.389	35.398	35.414	35.416	35.412	35.385	35.366	35.392	35.385	35.405	35.427	1983
1984	35.426	35.423	35.414	35.413	35.415	35.401	35.376	35.359	35.363	35.370	35.403	35.409	1984
1985	35.394	35.374	35.377	35.387	35.384	35.342	35.278	35.299	35.318	35.324	35.355	35.388	1985
1986	35.400	35.408	35.379	35.394	35.362	35.347	35.310	35.293	35.342	35.306	35.353	35.353	1986
1987	35.358	35.356	35.398	35.385	35.368	35.370	35.329	35.295	35.283	35.384	35.362	35.378	1987
1988	35.371	35.382	35.371	35.368	35.340	35.353	35.310	35.276	35.294	35.309	35.349	35.391	1988
1989	35.336	35.400	35.413	35.391	35.377	35.439	35.351	35.307	35.364	35.408	35.432	35.445	1989
1990	35.484	35.403	35.430	35.436	35.447	35.381	35.349	35.325	35.315	35.368	35.447	35.453	1990
1991	35.437	35.400	35.415	35.406	35.432	35.414	35.372	35.341	35.350	35.355	35.380	35.413	1991
1992	35.425	35.433	35.435	35.389	35.402	35.383	35.341	35.230	35.213	35.210	35.278	35.341	1992

Table 4(a). Anomalies of monthly mean temperature from 1951-1980 monthly mean values (interpolated values shaded)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1948	-0.16	-0.12	-0.08	-0.23	-0.50	-0.10	-0.46	-0.57	-1.12	-0.84	-1.22	-0.17	1948
1949	-0.27	0.01	-0.49	-0.32	-0.23	-0.93	1.32	-0.13	0.93	1.16	0.21	-0.73	1949
1950	-0.71	-0.23	0.05	0.02	-0.18	-0.38	-0.14	0.10	-0.07	-0.25	-0.43	-0.48	1950
1951	-0.54	-0.35	-0.33	-0.68	-0.06	0.56	0.72	0.89	1.05	0.78	0.52	0.53	1951
1952	0.24	-0.05	-0.34	0.28	0.08	-0.73	-0.19	0.95	-0.68	-0.25	-0.32	0.05	1952
1953	-0.05	0.08	0.52	-0.25	0.03	0.22	0.26	0.31	0.72	0.38	0.17	-0.05	1953
1954	0.19	-0.19	-0.18	-0.10	-0.27	0.42	-0.43	-0.56	-0.13	-0.34	-0.66	-0.50	1954
1955	-0.78	-0.09	0.02	0.29	0.06	0.47	1.14	1.76	1.02	0.28	0.58	0.48	1955
1956	0.00	0.15	0.27	0.40	-0.24	-0.71	0.09	-0.87	-0.58	0.05	0.27	0.24	1956
1957	0.64	0.75	0.59	0.73	0.52	0.05	0.91	0.69	0.64	-0.36	-0.11	0.51	1957
1958	0.45	0.41	0.32	-0.28	0.25	0.17	1.16	0.74	1.64	0.53	0.80	0.60	1958
1959	0.55	0.21	0.40	0.47	1.08	0.64	0.82	0.28	-0.03	0.71	0.95	0.46	1959
1960	1.20	0.65	0.64	0.62	1.29	0.93	1.63	1.19	0.76	0.67	0.49	0.17	1960
1961	0.25	0.20	0.39	-0.04	0.19	-0.27	-0.62	-0.73	-0.19	0.02	-0.05	-0.37	1961
1962	-0.34	-0.30	-0.23	0.22	-0.04	-0.62	-0.75	-0.45	-0.67	0.01	-0.22	-0.36	1962
1963	-0.43	-0.43	-0.35	-0.20	0.04	0.28	-0.28	-0.69	-0.86	-0.75	-0.12	-0.29	1963
1964	-0.10	0.20	0.20	0.08	-0.04	0.46	-0.43	-0.34	-0.51	0.06	0.22	-0.10	1964
1965	-0.31	-0.24	-0.28	-0.16	0.17	0.69	0.23	-0.24	-0.55	0.25	0.08	-0.15	1965
1966	-0.26	0.06	-0.08	-0.22	-0.36	0.10	0.47	0.17	-0.13	0.36	-0.52	-0.67	1966
1967	-0.01	0.01	-0.03	-0.07	-0.24	-0.03	-0.16	-0.71	-0.35	-0.72	-0.79	-0.33	1967
1968	-0.17	0.01	-0.45	0.40	0.00	0.26	0.23	1.85	0.91	0.04	0.18	0.18	1968
1969	0.22	0.27	0.18	0.12	0.04	0.69	-0.73	-0.17	0.13	-0.16	-0.30	-0.24	1969
1970	-0.04	-0.16	0.02	-0.04	0.03	0.72	-1.02	-0.35	-0.47	-0.32	-0.29	-0.20	1970
1971	0.04	0.39	0.32	0.10	0.08	-0.37	-0.41	-0.29	0.52	0.73	0.26	0.20	1971
1972	0.14	0.12	0.16	-0.20	-0.67	-1.23	-0.46	-1.33	-0.48	0.09	-0.34	-0.25	1972
1973	-0.17	-0.43	-0.11	-0.53	-0.28	-0.65	-0.58	-0.57	-0.27	-0.59	-0.45	-0.17	1973
1974	-0.17	-0.69	-0.20	0.72	0.27	-0.73	-0.13	-0.25	-0.55	-0.94	-0.59	-0.52	1974
1975	-0.46	-0.34	-0.26	-0.06	-0.32	-0.48	0.54	0.46	0.35	0.11	0.67	0.15	1975
1976	-0.13	0.03	-0.01	-0.26	-0.17	0.10	0.44	-0.27	1.35	0.55	0.23	-0.29	1976
1977	-0.01	0.01	-0.32	-0.58	0.03	0.29	-0.38	0.61	-0.52	0.06	-0.56	-0.35	1977
1978	-0.22	-0.51	-0.08	-0.66	-0.39	-0.42	-0.44	-0.65	-0.11	-0.02	0.20	0.52	1978
1979	0.04	0.09	0.00	-0.52	-0.97	-0.56	0.11	-0.47	-0.81	-0.07	-0.17	0.17	1979
1980	0.04	0.15	-0.25	0.40	-0.07	-0.23	-0.46	0.03	-0.17	-0.31	0.13	0.20	1980
1981	0.36	0.51	0.82	0.44	0.68	0.62	-0.31	0.13	0.92	-0.74	-0.16	0.25	1981
1982	0.16	0.06	0.22	0.38	-0.88	-0.66	-0.44	-0.22	-0.32	-0.42	0.25	0.30	1982
1983	0.15	0.00	-0.15	-0.30	-0.19	-0.25	-0.32	-0.38	-0.65				1983
1984						-0.26					-0.34	-0.42	1984
1985	-0.51	0.31	0.15	0.00	-0.80	-0.22	0.36	-0.52	-0.95	-0.65	-0.35	-0.05	1985
1986	-0.06	0.31	-0.23	0.15	-0.67	-0.36	-0.04	-0.77	-0.70	-0.54	-1.00	-0.75	1986
1987	-0.61	-0.39	-0.23	-0.12	-0.62	0.40	0.31	0.22	0.13	-0.69	0.05	0.00	1987
1988	-0.11	-0.29	-0.25	-0.35	-0.34	0.14	-0.22	-0.57	-0.20	-0.16	0.30	0.25	1988
1989	-0.36	0.31	-0.03	-0.30	-0.81	0.12	0.08	0.03	-0.70	-0.64	-0.17	0.60	1989
1990	0.39	-0.21	-0.01	-0.33	1.63	0.80	0.01	-0.34	0.41	-0.14	-0.07	0.04	1990
1991	0.14	-0.43	-0.02	-0.13	-0.10	0.19	0.48	-0.17	0.70	-0.51	-0.35	0.05	1991
1992	-0.11	-0.27	-0.44	-0.60	-0.84	-0.56	-0.29	-0.57	-1.65	0.07	-0.95	-0.33	1992

Table 4(b). Anomalies of monthly mean salinity from 1951-1980 monthly mean values (interpolated values shaded)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1948	-0.043	-0.025	-0.007	0.011	0.008	-0.017	0.003	0.002	-0.045	-0.006	-0.044	-0.052	1948
1949	-0.009	-0.052	-0.051	-0.059	-0.083	-0.030	0.015	-0.026	-0.063	-0.121	-0.032	-0.082	1949
1950	-0.130	-0.039	-0.009	-0.052	-0.102	-0.152	-0.135	-0.106	-0.094	-0.081	-0.069	-0.044	1950
1951	-0.018	-0.065	-0.031	-0.042	-0.019	0.004	0.035	0.066	0.097	0.070	0.043	0.018	1951
1952	0.002	-0.015	-0.031	-0.002	0.009	-0.037	0.062	0.027	0.051	0.042	0.083	-0.017	1952
1953	-0.013	0.018	-0.008	-0.034	-0.021	-0.003	-0.004	-0.004	-0.098	-0.111	-0.074	-0.037	1953
1954	0.037	0.025	-0.021	-0.044	-0.014	0.028	0.055	0.036	-0.012	-0.011	-0.073	-0.073	1954
1955	-0.048	0.007	-0.011	-0.008	0.008	-0.030	-0.064	-0.043	-0.007	0.029	-0.025	-0.011	1955
1956	-0.005	0.040	0.011	0.036	0.068	0.048	0.010	0.009	0.055	0.065	0.068	0.037	1956
1957	0.043	0.051	0.029	0.058	0.057	0.010	0.025	0.060	0.048	0.027	0.025	0.023	1957
1958	0.032	-0.010	-0.010	0.036	0.030	0.026	-0.005	0.076	0.028	0.098	0.068	0.051	1958
1959	0.058	0.050	0.059	0.033	0.073	0.044	0.049	-0.019	-0.003	0.025	0.039	0.028	1959
1960	0.038	-0.009	0.020	0.049	0.050	0.031	-0.036	0.049	0.025	0.064	0.039	0.035	1960
1961	0.028	0.012	0.046	0.002	-0.003	0.018	0.037	0.003	0.010	-0.009	-0.012	-0.001	1961
1962	0.010	0.021	0.023	-0.062	0.023	-0.033	-0.068	-0.124	-0.045	-0.103	-0.095	-0.083	1962
1963	0.015	0.006	0.018	0.022	0.006	-0.010	0.020	-0.006	-0.013	-0.025	-0.046	-0.011	1963
1964	0.002	0.012	0.032	0.016	-0.010	-0.019	0.009	0.004	-0.043	-0.025	-0.034	-0.015	1964
1965	-0.011	-0.006	0.009	0.017	0.032	-0.035	0.013	0.062	0.061	0.087	0.063	0.063	1965
1966	0.027	0.058	0.048	0.081	0.053	0.050	0.054	0.089	0.091	0.116	0.101	0.047	1966
1967	0.067	0.055	0.056	0.057	0.060	0.070	0.090	0.081	0.061	0.089	0.071	0.040	1967
1968	0.042	0.052	0.084	0.031	-0.005	0.012	0.025	0.042	0.006	-0.022	-0.034	-0.042	1968
1969	0.015	0.020	0.016	0.041	0.003	0.031	0.043	-0.005	-0.010	0.002	0.056	0.016	1969
1970	0.024	0.037	0.036	0.044	0.031	0.018	0.028	0.035	0.020	0.042	0.031	0.033	1970
1971	0.039	0.014	0.024	0.024	0.011	0.034	0.020	0.049	0.027	0.017	0.010	0.053	1971
1972	0.002	0.011	0.037	0.009	-0.049	-0.067	-0.035	-0.046	0.021	0.010	0.030	0.000	1972
1973	0.014	0.008	-0.044	-0.023	-0.011	-0.003	-0.024	-0.026	0.001	0.014	-0.029	-0.038	1973
1974	-0.032	-0.070	-0.033	-0.041	-0.063	-0.081	-0.066	-0.068	-0.106	-0.096	-0.091	-0.086	1974
1975	-0.081	-0.057	-0.059	-0.086	-0.078	-0.069	-0.096	-0.102	-0.151	-0.203	-0.165	-0.142	1975
1976	-0.120	-0.074	-0.082	-0.084	-0.096	-0.049	-0.075	-0.111	-0.025	-0.048	-0.052	-0.058	1976
1977	-0.059	-0.101	-0.068	-0.058	-0.045	-0.050	-0.055	-0.055	-0.062	-0.069	-0.022	-0.017	1977
1978	-0.051	-0.074	-0.049	-0.054	-0.070	-0.071	-0.050	-0.068	-0.104	-0.021	-0.085	-0.089	1978
1979	-0.051	-0.026	-0.018	-0.024	-0.034	0.017	-0.027	0.011	0.005	0.013	-0.030	-0.004	1979
1980	0.004	-0.012	-0.014	0.015	0.022	0.068	0.065	0.048	0.002	0.015	0.074	0.041	1980
1981	0.007	0.023	-0.015	-0.034	-0.044	-0.052	-0.081	-0.063	-0.046	-0.024	0.005	0.004	1981
1982	0.009	0.014	0.011	0.008	0.002	0.020	0.037	0.055		0.050	0.050	0.050	1982
1983	0.022	-0.006	0.007	0.020	0.015	0.020	0.025	0.030	0.059	0.052	0.046	0.040	1983
1984	0.033	0.028	0.023	0.019	0.014	0.009	0.016	0.023	0.030	0.037	0.044	0.022	1984
1985	0.001	-0.021	-0.014	-0.007	-0.017	-0.050	-0.082	-0.037	-0.015	-0.009	-0.004	0.001	1985
1986	0.007	0.013	-0.012	0.000	-0.039	-0.045	-0.050	-0.043	0.009	-0.027	-0.006	-0.034	1986
1987	-0.035	-0.039	0.007	-0.009	-0.033	-0.022	-0.031	-0.041	-0.050	0.051	0.003	-0.009	1987
1988	-0.022	-0.013	-0.020	-0.026	-0.061	-0.039	-0.050	-0.060	-0.039	-0.024	-0.010	0.004	1988
1989	-0.057	0.005	0.022	-0.003	-0.024	0.047	-0.009	-0.029	0.031	0.075	0.073	0.058	1989
1990	0.091	0.008	0.039	0.042	0.046	-0.011	-0.011	-0.011	-0.018	0.035	0.088	0.066	1990
1991	0.044	0.005	0.024	0.012	0.031	0.022	0.012	0.005	0.017	0.022	0.021	0.026	1991
1992	0.032	0.038	0.044	-0.005	0.001	-0.009	-0.019	-0.106	-0.120	-0.123	-0.081	-0.046	1992

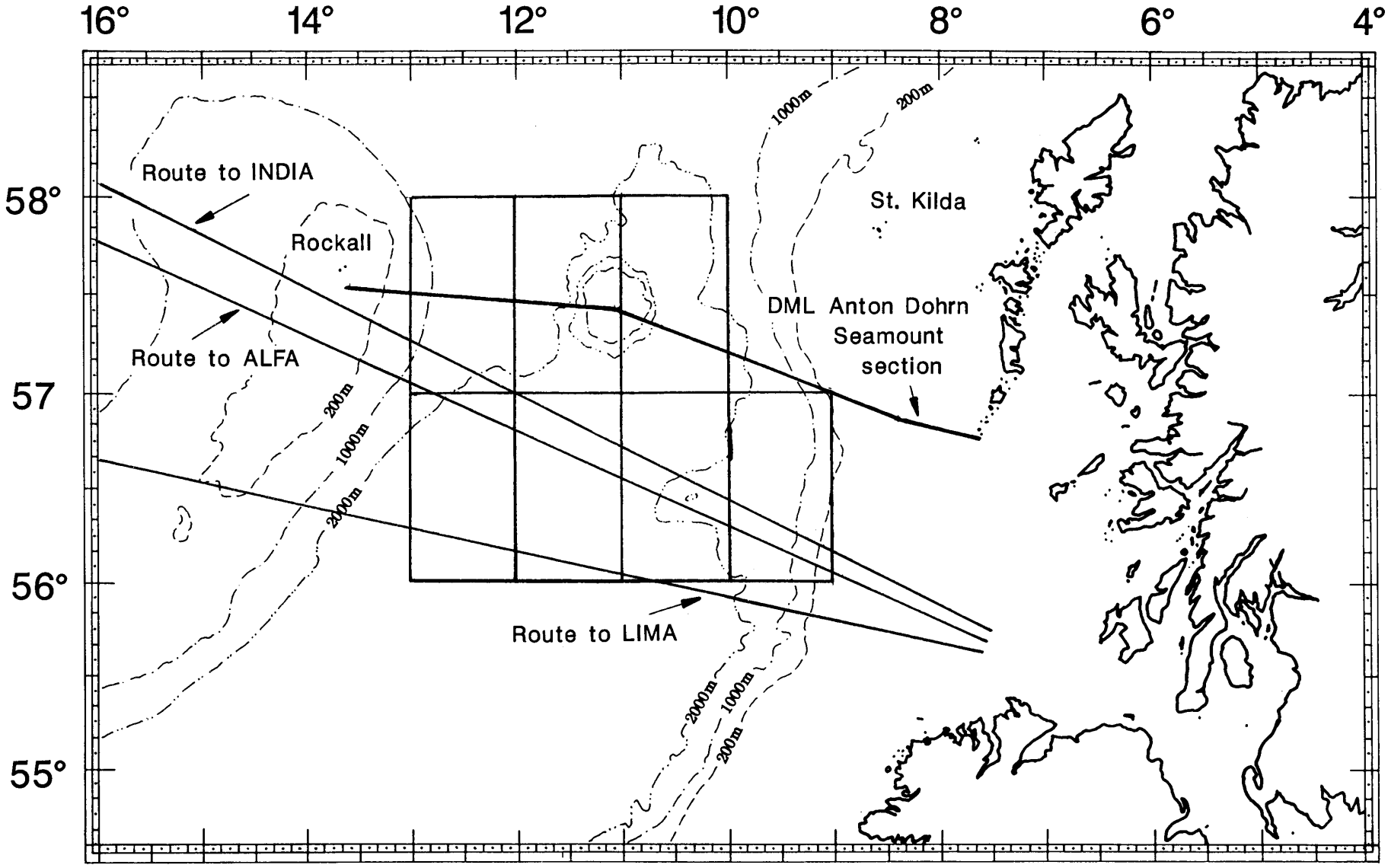

Figure 1. Location of the seven 1° x 1° rectangles from which the time-series data were obtained and the approximate routes across the area from which surface samples have been obtained

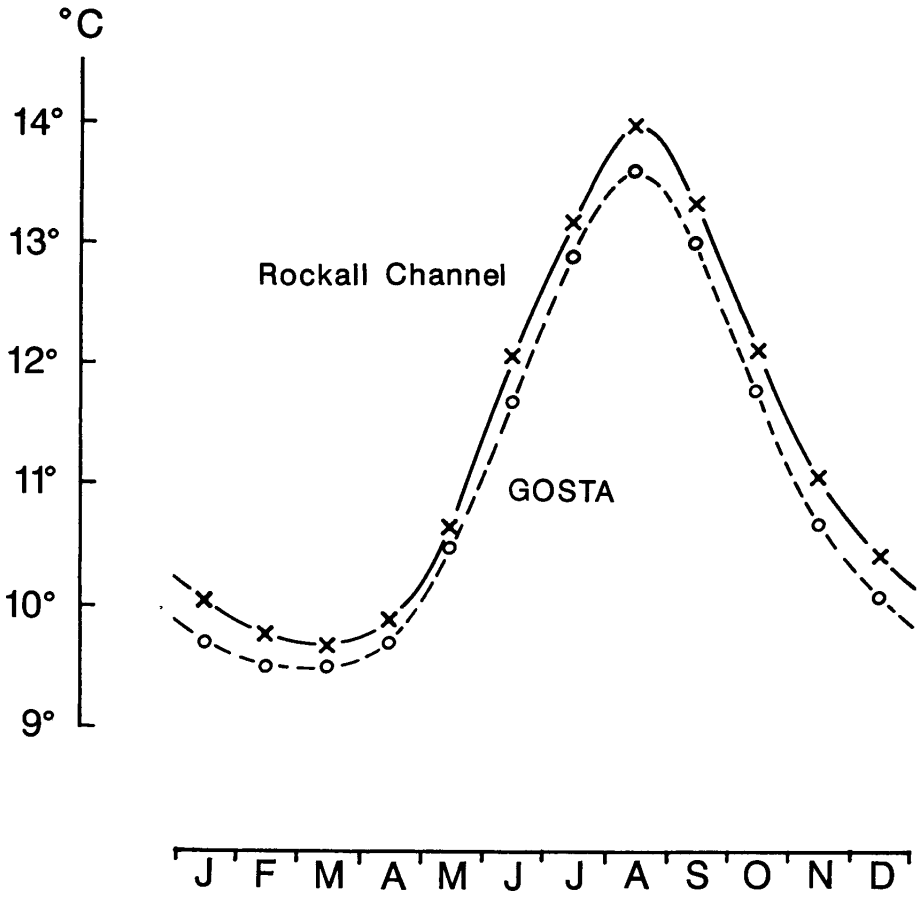

Figure 2(a). Annual cycle of surface temperature in the central Rockall Channel from 1951-1980 means. The GOSTA (1990) means for the 5° x 5° rectangle 55°-60°N, 10°- 15°W for the same period are also shown

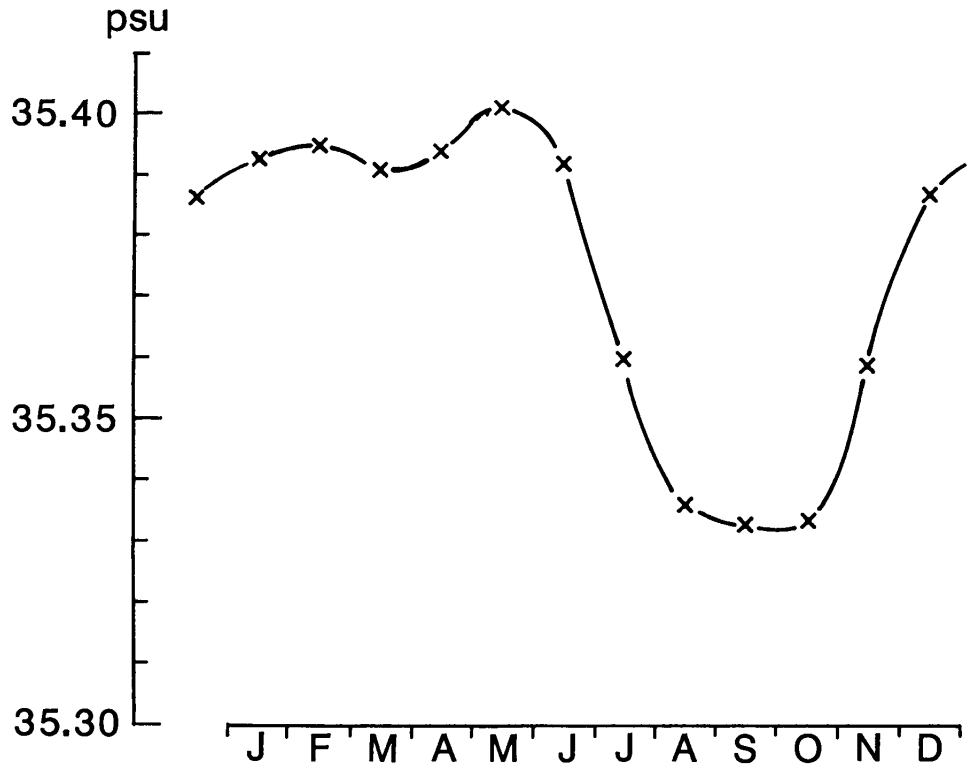

Figure 2(b). Annual cycle of surface salinity in the central Rockall Channel from 1951-1980 means

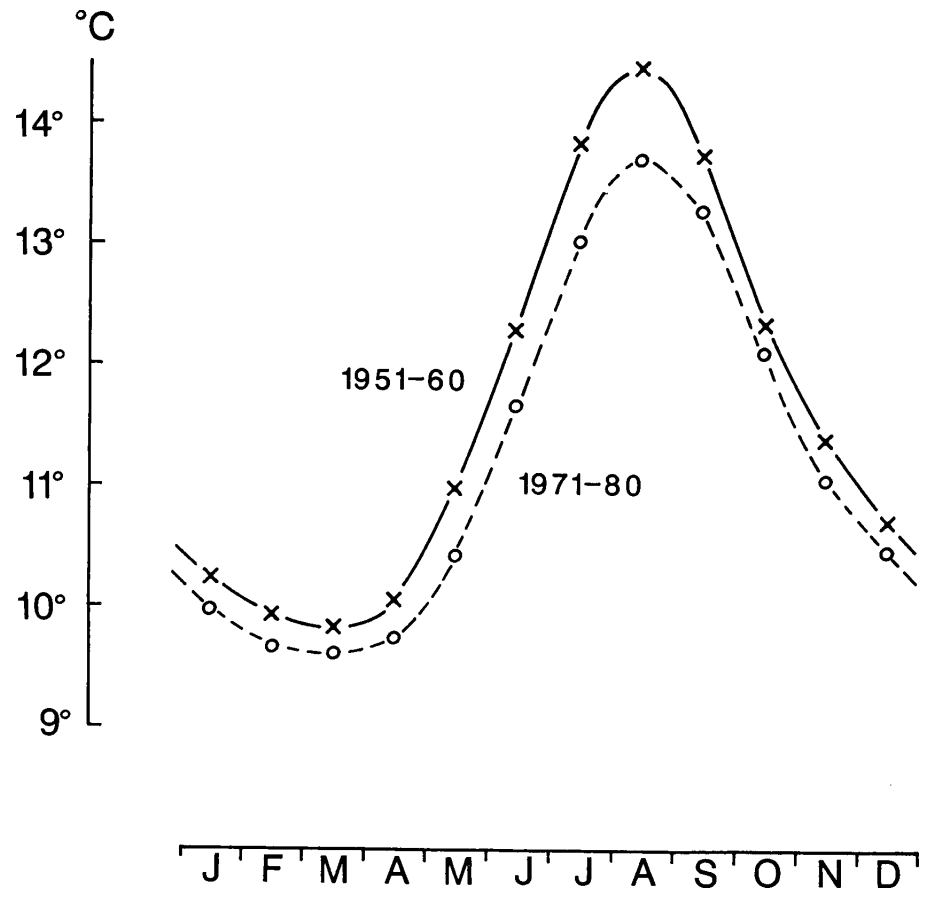

Figure 3(a). Annual cycles of surface temperature in the central Rockall Channel for the 1951-60 and 1971-80 decadal means

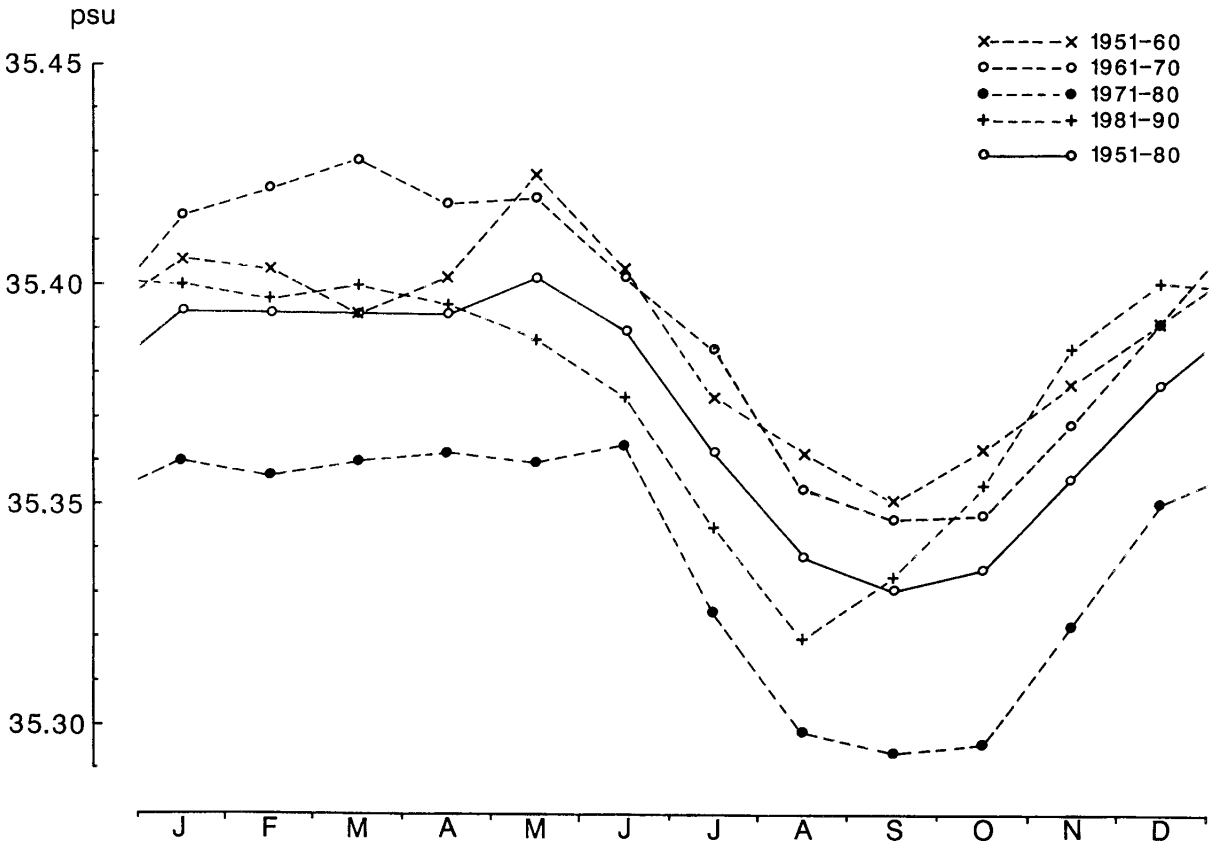

Figure 3(b). Annual cycles of surface salinity in the central Rockall Channel for four decades

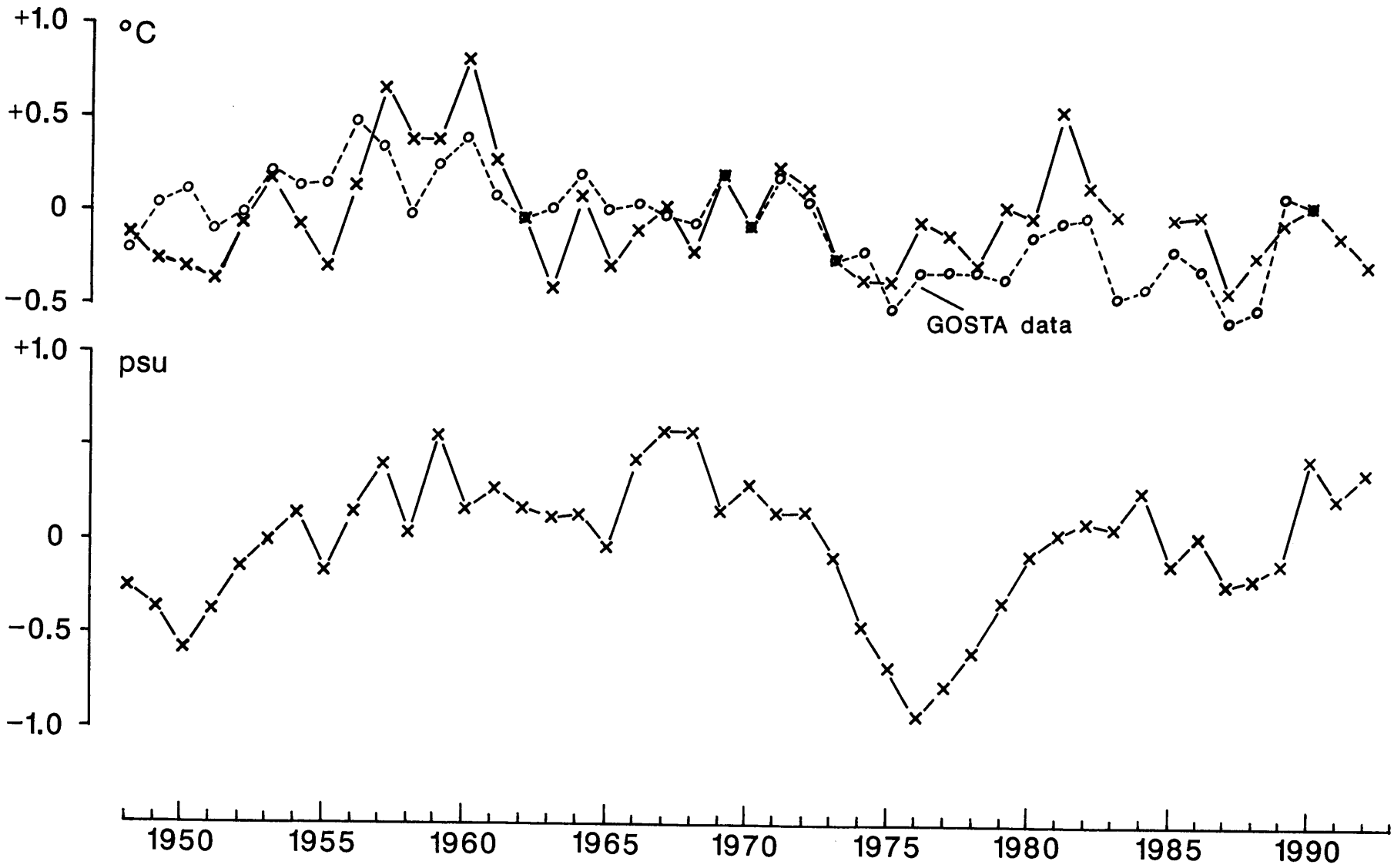

Figure 4. *Mean winter (January - March) surface temperature and salinity anomalies from 1950-1980 mean values for the central Rockall Channel, 1948-1992. Also shown are the mean winter (January - March) surface temperature anomalies for the area 55°- 60°N, 10°- 15°W from the GOSTA (1990) data set*

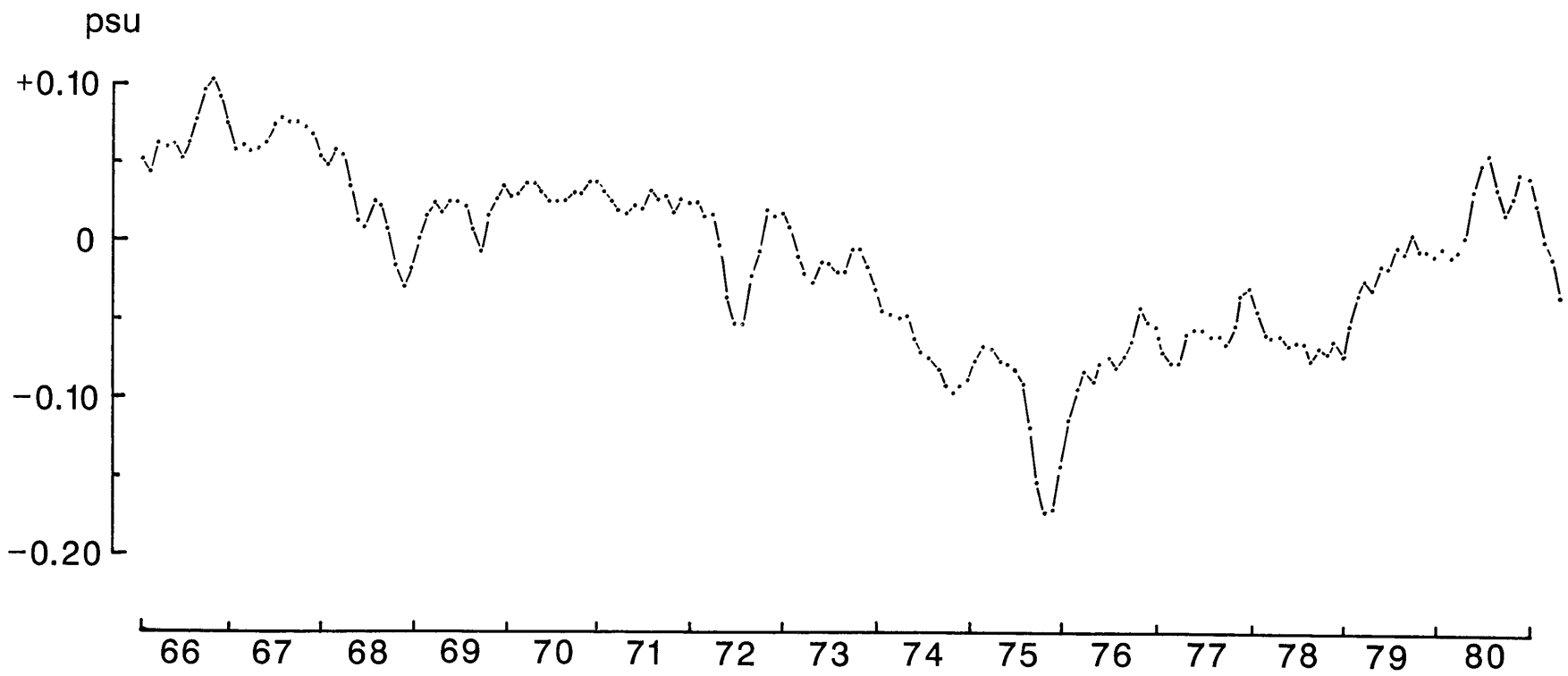

Figure 5. Running 3-monthly means of surface salinity anomalies from 1950-1981 means for the period 1966-1980

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