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Met O 3 Technical Note No 11

An Index of Windiness for the United Kingdom

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1. Introduction

In many aspects of wind speed climatology it would be helpful to know the windiness of a month, season or year over a wide area of the country relative to a long period average. For example, in the Climatological Services Branch (Met O 3) requests are often received for mean monthly and mean annual wind speeds for various places in the U.K. These are answered by supplying appropriate statistics based on as much data as in available (but taking due regard to the homogenity of observations). In some cases less than ten years of data exist and the question arises as to how representative the mean wind speeds in this period are in relation to the long term wind speed climate. To take another example, in the Climatological Research Group (part of Met O 3) an attempt is being made to model the time series of hourly mean speeds for different locations in the U.K. The model is based on observed data and because the periods for which data exist on a computer compatible medium are relatively short and cover different years at different stations it is necessary to know the relative windiness of the years in question.

As far as can be ascertained, an indicator of relative windiness has not yet been devised for the U.K. Various reasons may account for this:

(i) Any study of wind speeds at different stations is complicated by the fact that speeds can vary substantially over short distances in the vertical and in the horizontal, particularly at the heights at which speeds for climatological purposes are recorded. The exposure of anemometers in the UK varies from station to station and although an effective height of 10 m is the recommended standard many stations have their instruments positioned at other heights; they may be on the tops of buildings, for example.

(ii) At any one station there may have been changes in the type of anemograph and/or changes of site. Many stations observing during the 1950s and 1960s replaced a pressure tube anemograph (PTA) by a Mark 2 (and subsequently a Mark 4) cup generator anemograph (CGA). Work by the present author indicates that Mark 2 and Mark 4 CGA speeds are on average about 1-2 kn higher than PTA values (Smith (1981)). It is also possible that readings from the Mark 5 CGA, recently installed at several UK stations, are not consistent with those from the Mark 2 and Mark 4. Site changes can also occur quite frequently (for reasons such as the construction of buildings close to the anemometer) and speeds from one site are often not consistent with speeds at another.

(iii) Wind speed records held by the Meteorological Office are available for few stations before 1956 and data for many stations since then are non-homogeneous (for reasons outlined above) or incomplete. Little data exist for areas in inland Wales or mainland Scotland away from the coasts and the Central Lowlands.

Despite these problems, work has been undertaken to devise an index of windiness using stations that appeared to provide a reasonably long period homogeneous record of wind speeds. Indices were determined initially on a monthly basis and then means of successive monthly indices were taken to construct seasonal and annual values. In the second part of this paper a procedure for estimating index values based on surface pressure gradients is described and results given. Estimates have been produced for months from January 1881 onwards, well before anemograph observations become available.

2. Index values based on anemograph data

2.1 Stations and data

A total of 28 UK stations submitting hourly anemograph data have a potentially homogeneous and reasonably continuous record of observations between 1965 and 1979 inclusive. The spatial variation of annual means between 1965 and 1979 at these stations relative to their 1965-79 averages was examined. Values for some stations were often found to be inconsistent with corresponding observations at neighbouring stations. Such stations were omitted from subsequent work. Several stations were also excluded either because they were located in an isolated position relative to the remainder of the UK (eg. Lerwick) or in cases where there were two or more stations in close proximity. The number of stations was thus reduced to 17 and their locations are shown in fig. 1. The regions delineated are discussed later.

With the exception of Benbecula, Leeming and Honington each of these stations has, for the period 1965-79,

(i) no more than 170 missing observations in any month, of hourly mean speeds recorded each hour of the day (in total there are only four station months that have more than 75 missing values),

(ii) no recorded change of instrument from a PTA to a CGA,

(iii) no recorded site change.

At Benbecula there was a site and instrument change on April 1st 1965. For Leeming and Honington data are only available from December 1965 and October 1969 respectively.

Monthly mean speeds were determined for all stations for each month from January 1965 to December 1979. Missing values for Leeming were estimated from Ringway data. For Honington, data from Mildenhall (only 25 km from Honington) were used to derive estimates for the period 1965-1968, with Elmdon speeds used for estimating values for January-September 1969.

2.2 Formulation of index

An index of windiness based solely on the absolute magnitude of the wind speed at different stations would be unsatisfactory because its value would depend greatly on the particular stations chosen. The index is therefore based on the standardised anomaly of each month's speed relative to a long period monthly average.

The average and standard deviation of the monthly means from 1965 to 1979 were calculated for each of the 17 stations and for each month of the year. The difference of the month's mean speed from the long period monthly average was then determined and expressed as a proportion of the standard deviation. So, for each station a series of y_i were obtained, where

$$y_i = \frac{x_i - \bar{x}}{\sigma} \qquad - (1)$$

with y_i the standardised anomaly for month i

x_i the monthly mean

and $\bar{x}$, σ the 1965–79 average and standard deviation of the means for the month in question.

The distributions of the y_i's have zero mean but are somewhat positively skewed because positive anomalies of monthly mean speeds tend to be larger in absolute value than negative anomalies.

The values of y_i for each station are shown for January 1974, a windy month, and for August 1976, a month with below average speeds, in figs 2a and 2b respectively.

It was observed, quite frequently, that the standardised anomalies varied considerably across the country in a consistent fashion (although not in figs 2a and 2b above). It therefore seemed appropriate, for the purpose of formulating a windiness index, to divide the UK into regions. In general the spatial correlation of wind speed is greater in an east-west direction than a north-south direction, owing to the predominantly zonal movement of synoptic features at mid-latitudes. A north-south division of regions was therefore chosen and the regions are shown in fig. 1. The south region contains five stations and the others, six stations each.

The final step in deriving the index (I) was, for each region and for each month, to take the arithmetic mean of the y_i values over the stations within the region. This averaging reduces the effects of any inconsistent values in a region and should produce a quantity which is more representative of the region as a whole than could be obtained from any single station.

Winter (October to March), Summer (April to September) and annual (January to December) indices were also derived for each region by averaging the monthly indices over the appropriate months, then expressing each value as a proportion of the standard deviation for the season (or year) over the period 1965–79. For example, the index for Summer, year k, is given by

$$S_k = \frac{\frac{1}{6}\sum_{j=4}^{9} I_j}{\sigma_{\bar{I}}}$$

where the I_j are the indices for month j and $\sigma_{\bar{I}}$ is the standard deviation of the averaged monthly indices.

Index values have now also been calculated for 1980 data.

2.3 Results

In what follows I_N, I_c and I_s will denote the indices for the north, central and south regions respectively, I the collective term for these indices and the adjective "quiet" will be used as an antonym of "windy". I_N, I_c and I_s are shown for January and July 1965–80 in figs 3a, b. A noticeable feature of fig 3a is the run of windy January's between 1974–76. The quietest months were 1973 and 1980. The plots for July indicate that July 1970 and 1974 were windy and 1972, 1973 were quiet. Considerable regional differences exist for July 1969 – it was windy in the north but quiet in the south.

I_N, I_c and I_s are displayed for Winter and Summer in figs 4a, b. In fig 4a the values are plotted against the year in which January–March fall. Taking the three regions together, the windiest Winter in the period was 1966–67 and the quietest, 1976–77. For Summers (fig 4b), 1965, 1967 and 1970 were windy and 1968 (except the south), 1971 and 1976 were quiet.

Annual indices are plotted for all three regions in fig 5. 1967 was the windiest year overall with 1971 and 1976 the quietest.

3. Estimated index values based on surface pressure gradients

3.1 Preliminaries

It was not feasible to produce index values based on anemograph data for years prior to 1965 because the number of stations with homogeneous data extending from before 1965 to at least 1979 decreases rapidly as one goes back in time. The possibility of using daily surface pressure values (which are available from January 1st 1881 onwards) to derive wind speeds and hence indices was therefore explored.

The Synoptic Climatology Branch of the Meteorological Office has produced time series of daily "flow indices" (FI) for various grid points around the British Isles, obtained from surface pressure gradients at midnight or midday. The FI are equivalent to geostrophic speeds at 55°N 5°W and are approximate geostrophic speeds at other grid points. Details of the derivation of FI are given in the appendix. FI from just six grid points were used to estimate I and these six are shown in fig 6.

Monthly FI were produced for these grid points from January 1881 to December 1980 by averaging the daily values. Unfortunately the data are not homogeneous because the grid point surface pressures have been obtained from different sources based on different analysis schemes. (See Benwell (1976) for the various sources). Jenkinson and Collison (1977) suggest adjustment factors to homogenise high values of FI. These are given in table 1 and have been applied to the monthly FI although strictly the adjustments were intended for analysing gales.

Means and standard deviations of monthly FI were calculated for each month of the year and over the same period for which I had been determined, namely 1965–79. Monthly standardised FI (SFI) were then produced using the form of equation (1) for each grid point from 1881 onwards.

3.2 Estimation procedure

It was next required to estimate I_N, I_c and I_s using the six grid point SFI as predictors. To obtain the regression equations the stepwise regression computer program BMDP2R, available in the BMDP statistical package (Dixon and Brown (1979)), was run on 192 monthly values - January 1965 to December 1980 inclusive - of I_N, I_s and I_c separately with corresponding grid point SFI.

The resulting regression equations are presented on the left hand side of table 2. The BMDP "all sub-sets regression" program (BMDP9R) was applied to subsets of the sample of 192 cases to study the mathematical stability of the results. It was found that the number of grid points entered into the equations shown in the table is optimum and that the coefficients given are fairly stable. However the particular set of grid points giving the least root-mean-square error is in general not unique for different sub-sets of cases, a result which arises from the high correlation between SFI at neighbouring grid points. This high correlation means that the grid points used as predictors are not necessarily those closest to the region in question.

The standard error of the residuals and the squared multiple correlation coefficient are also shown in table 2. The magnitude of the latter, representing the fraction of the variance of I explained by the regression, indicates that the estimates are reasonable approximations to I_N, I_c and I_s.

The variance of the estimated indices (which will be denoted by $\hat{I}_N$, $\hat{I}_c$ and $\hat{I}_s$) was observed to be about 15% less than the variance of the actuals. This arises from the smoothing inherent in the regression equations. $\hat{I}_N$, $\hat{I}_c$ and $\hat{I}_s$ were therefore multiplied by appropriate factors to restore the original variances.

Finally seasonal and annual estimates were determined from the monthly values by averaging and standardising, as carried out for the actual indices.

3.3 Comparison between estimated and actual index values

Fig 7 displays I_s and $\hat{I}_s$ for January and July between 1965 and 1980. The standard error of the estimates is greater for July and in general there is a slight tendency for errors to be larger for the Summer months compared to Winter months. This is possibly because winds are lightest in Summer and the relationship between pressure differences and surface wind speeds is weakest in such conditions. The plots visually confirm that the estimates are reasonable indicators of I_s. Annual values of the actual and estimated indices are shown for all three regions in fig 8. Again the year to year variation in the actual values is well reflected by the movement of the estimated indices. There does appear to be a bias in the estimates, particularly those for the north, in that the estimates tend to be lower, relative to the actuals, before 1972 than in subsequent years. This may arise from a change in the analysis of surface pressures around 1972.

3.4 Results

The estimated index values need to be treated with some caution, not only because they are estimates and are therefore subject to error but also because it is probable that the effects of the inhomogeneities present in the surface pressure data have not been completely removed by the adjustments made to FI. However the estimates should provide a useful guide to the relative windiness of a month, season or year.

Annual means of the estimated indices are plotted for the different regions in fig 9. There is a relatively quiet period between 1930 and 1947 for the north and central regions and the period since 1968 has given a high proportion of below average speeds for all regions. The values for a number of years show large variations between regions e.g. for 1882, 1898, 1965 and 1973.

Tables 3a, b give the windiest and quietest months, seasons and years for each region over the period 1881-1980 based on estimated values throughout. Considering table 3a first, the only month to be the windiest in all regions is February 1903; note also that the following month, March 1903, is the windiest March for two regions. Examination of daily weather summaries for February and March 1903 indicated that during these months a succession of vigorous depressions passed over or close to the British Isles. The distribution of windiest months through the 100 years is fairly even. For the quietest averages (table 3b), June 1895 and December 1890 are extreme months for all three regions. Study of weather summaries revealed that the atmospheric circulation at those times over the British Isles was strongly anticyclonic. The most recent years have given several extremes, a feature which is particularly noticeable on the seasonal and annual time scale.

Finally to present the indices for all months together in a convenient form the monthly values for each region have been averaged and are shown in table 4. Again estimated values have been used throughout. Occasions when the range of values of $\hat{I}_N$, $\hat{I}_c$ and $\hat{I}_s$ exceeds 1.5 are marked with an asterisk; for these months the variation in windiness across the UK is thus relatively large. The windiest month (relative, of course, to the 1965-79 mean for that month) is seen to be February 1903 and the quietest months are the Novembers of 1942, 1945 and 1958. One interesting feature of the values is the small number of Augusts with below average speeds between 1881 and 1930.

4. Future calculation of index values

Already since 1980 (i) Kew Observatory has closed and (ii) the Mark 4 anemometer at Elmdon has been replaced by a Mark 5 and moved to a different site. Inevitably there will be further closures, changes of site or changes of instrument at other stations used in the calculation of the windiness indices, reducing their usefulness for the estimation of windiness for periods after 1980. Barometer readings from individual stations could be used instead but due to non-availability of data it is not possible at present to derive windiness indices extending very far back in time using such values. The daily grid point surface pressures may therefore be the most satisfactory indicators of windiness for future climatological studies on a large scale. This is with the proviso that any inhomogeneities in time introduced into the surface pressure data by alterations to the Meteorological Office numerical analysis scheme (from which surface pressure values are currently obtained) are insignificant or can be allowed for.

5. Summary

An index of monthly windiness has been formulated for three regions covering the UK. Values of the index have been determined from observed monthly mean wind speeds for each month from January 1965 to December 1980. Seasonal and annual index values have also been calculated and presented. Daily surface pressure gradients have been used to estimate index values for months, seasons and years between 1881 and 1980.

The index can be used to gauge the representivity of wind speeds in a period of five years, say, in relation to speeds from a longer period. It can be used by climatologists interested in the relative windiness of individual months, seasons and years and by those investigating climatic change, although for this purpose care is needed due to the possible inhomogeneity of the grid point data. A further possible application is in the long-term quality control of wind speeds at individual stations.

6. References

Benwell, P R	1976	Standard contour data sets. Met O 13 Data Processing Section Tech. Note No. 7
Dixon, W J and Brown, M B	1979	Biomedical Computer Programs, P-Series. Univ. of California Press. Program revision dates both Nov 1979. Programs were developed at Health Sciences Computing Facility, UCLA. The Health Sciences Computing Facility was sponsored by NIH Special Resources Grant RR-3.
Jenkinson, A F and Collison, P	1977	An initial climatology of gales over the North Sea. Syn. Clim. Branch Mem. No. 62.
Smith, S G	1981	Comparison of wind speeds recorded by pressure tube and Meteorological Office electrical cup anemographs. Meteorological Magazine, 110, pp 288-301.

APPENDIX

Derivation of daily flow indices from surface pressures.

Let A, B, C, ... denote surface pressures at midnight or midday at indicated grid points.

	10° W	0	10° E
65° N	× A	× B	× C
60° N	× D	× E	× F
55° N	× G	× H	× I
50° N	× J	× K	× L
45° N	× M	× N	× O

Then, for example, to determine the daily flow at 55°N 5°W :

Westerly Flow W along 55°N $= \frac{1}{2}(J + K) - \frac{1}{2}(D + E)$

Southerly flow S along 5° W $= 1.74 \left\{ \frac{1}{4}(E + 2 \times H + K) - \frac{1}{4}(D + 2 \times G + J) \right\}$

Resultant daily flow at 55°N 5°W $= (W^2 + S^2)^{\frac{1}{2}} \times 1.2$ kn

Similar expressions hold for the flow at the other 5 grid points shown in fig 6.

(Information obtained from Synoptic Climatology Branch, D.P. Section Technical Note no. 12)

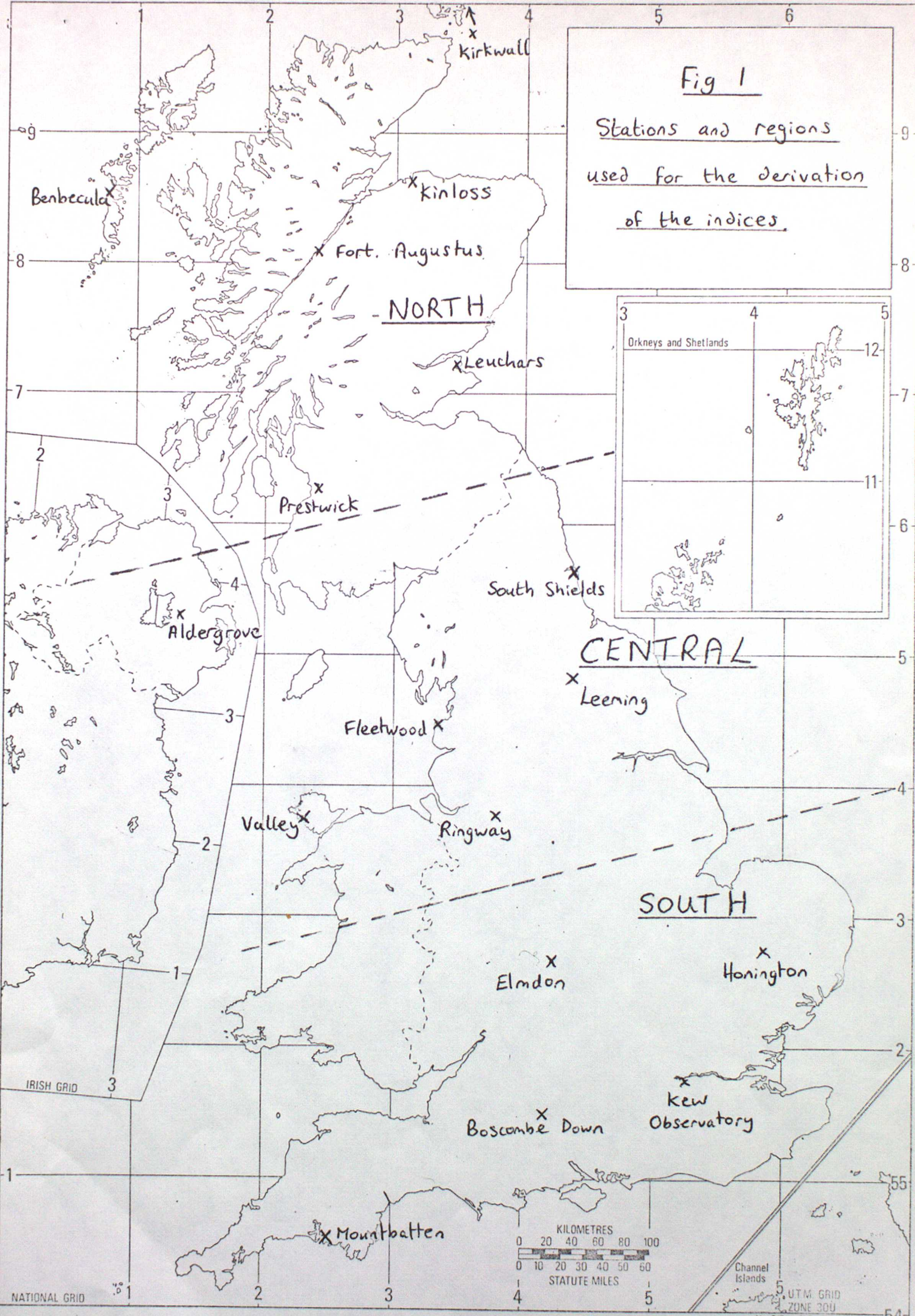


Fig 1

Stations and regions used for the derivation of the indices.

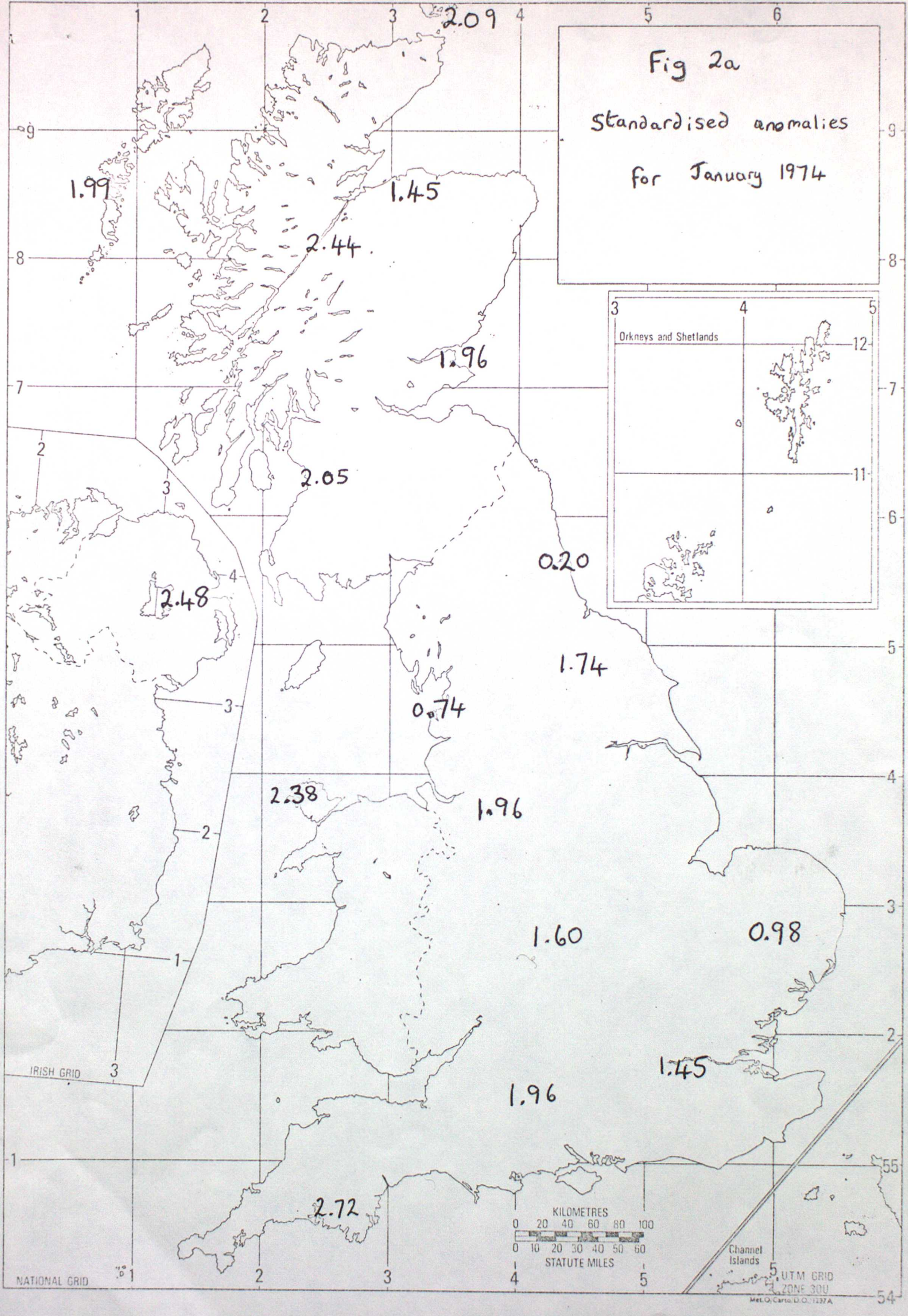


Fig 2a

Standardised anomalies for January 1974

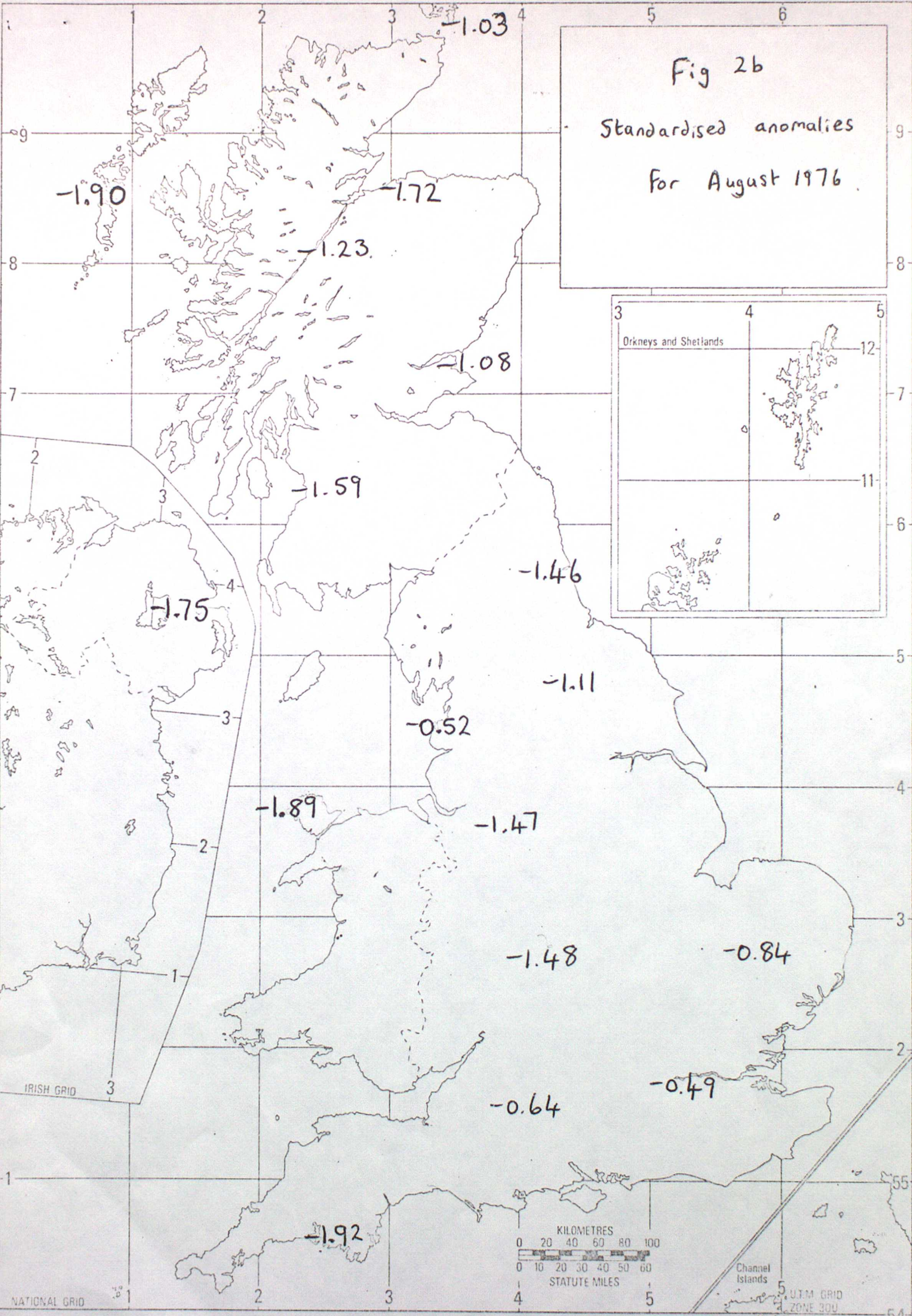


Fig 2b
Standardised anomalies for August 1976

Fig 3a

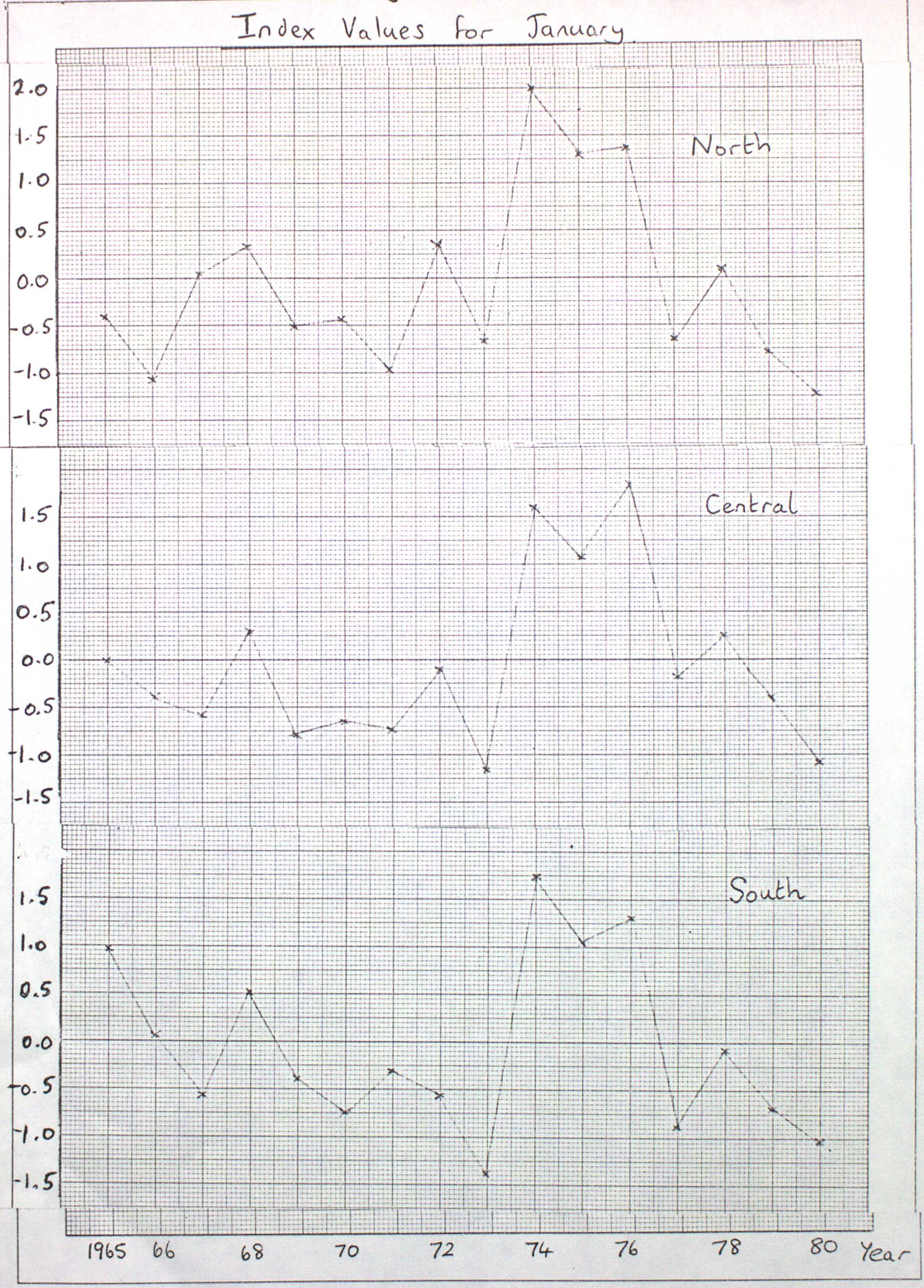

Index Values for January
North
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
Central
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
South
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
1965
66
68
70
72
74
76
78
80
Year

Fig 3b

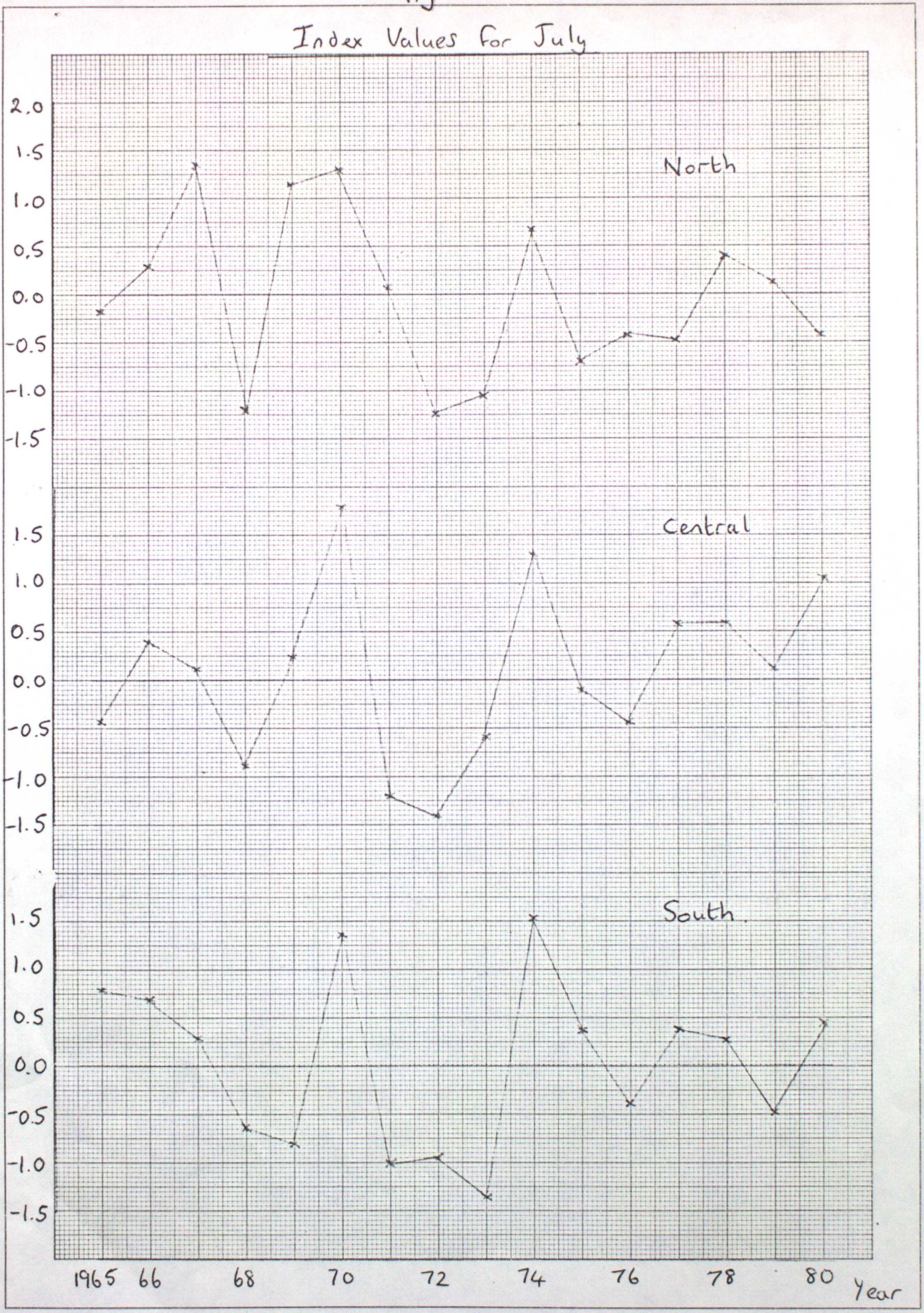

Index Values for July
North
Central
South
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
1965
66
68
70
72
74
76
78
80
Year

Fig 4a

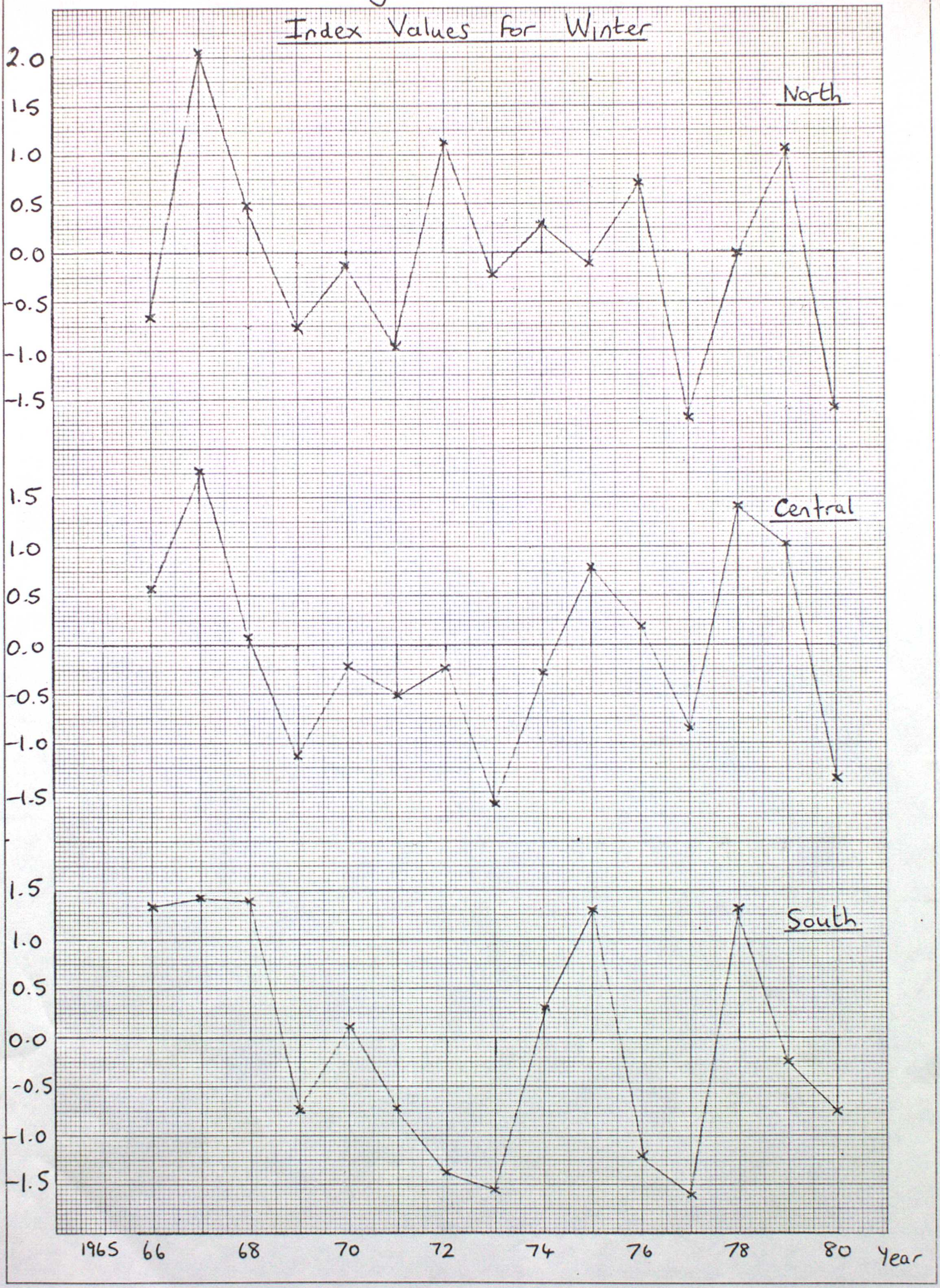

Index Values for Winter
North
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
Central
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
South
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
1965
66
68
70
72
74
76
78
80
Year

Fig 4b

Index Values for Summer

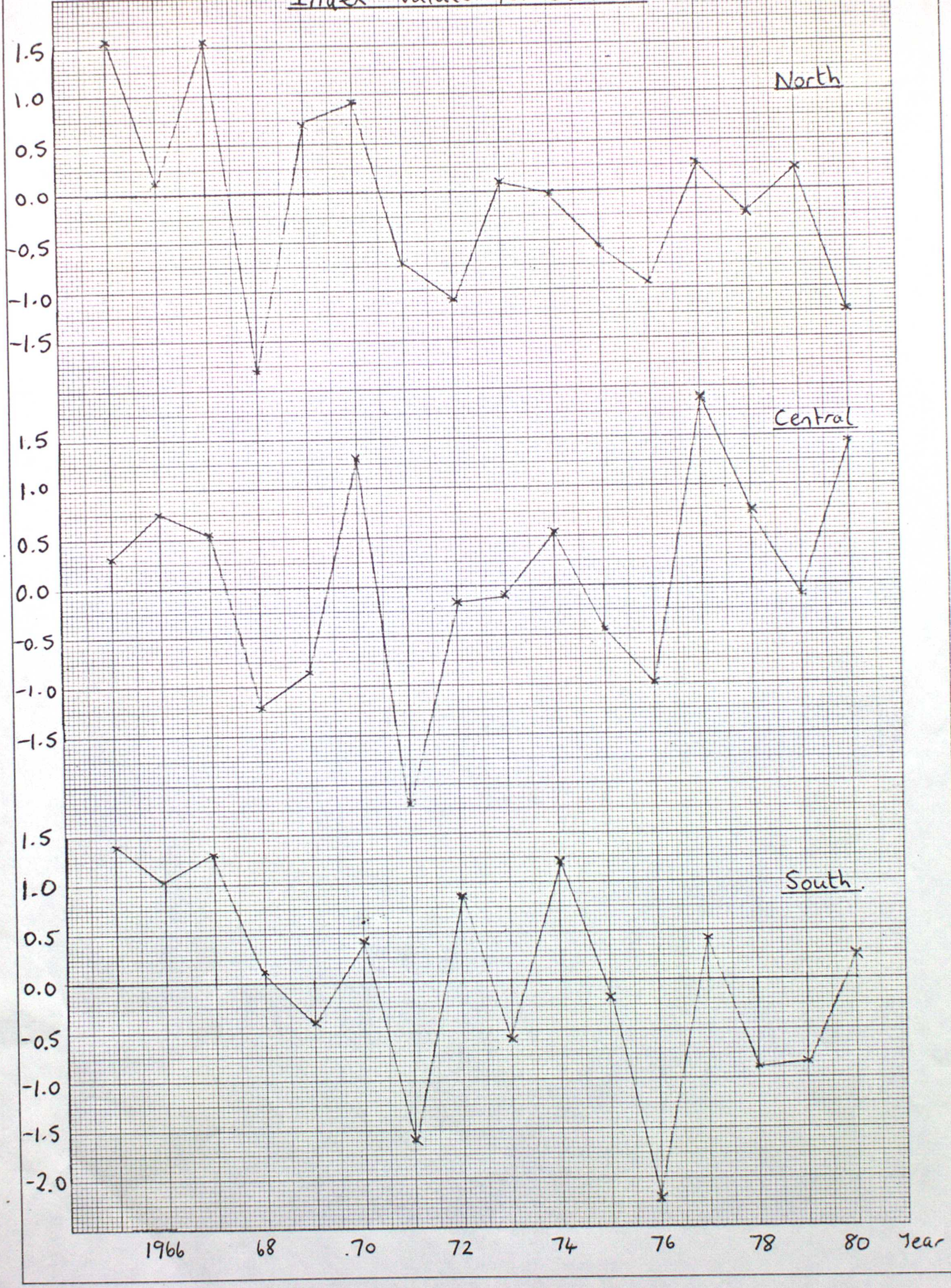


Fig 5

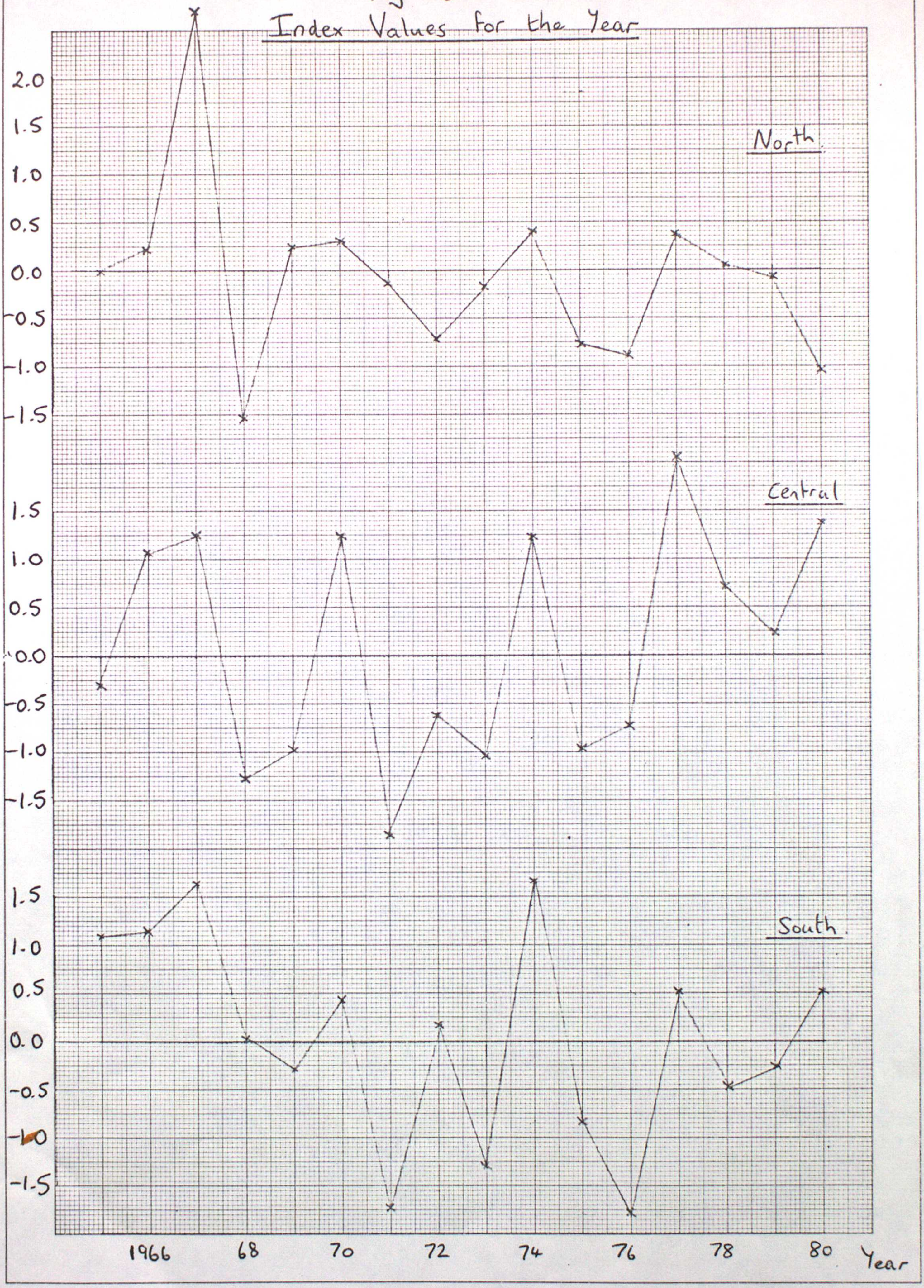
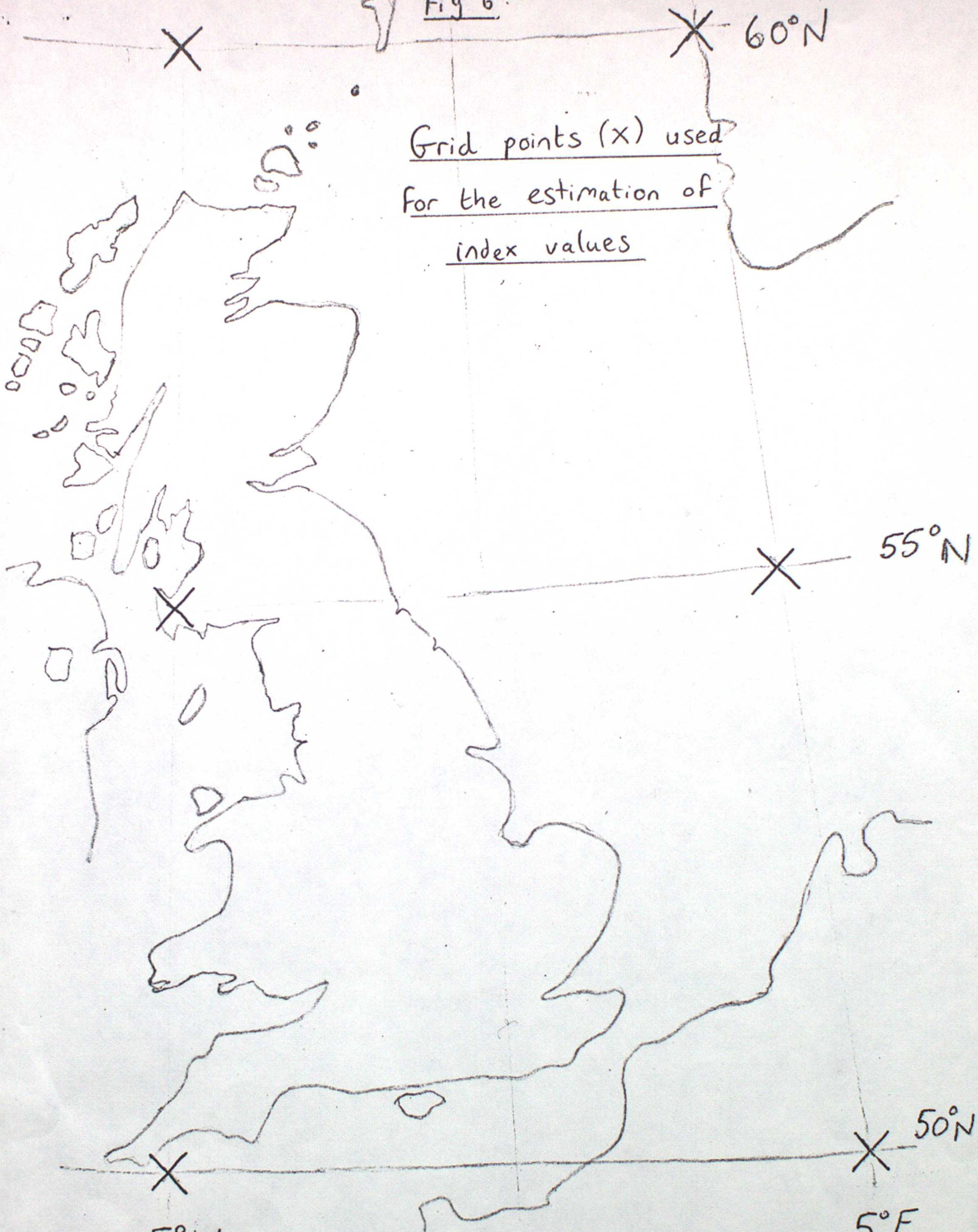

Index Values for the Year
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
North
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
Central
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
South
1966
68
70
72
74
76
78
80
Year

Fig 6.



60°N
Grid points (x) used for the estimation of index values
55°N
50°N
5°W
5°E

Fig 7

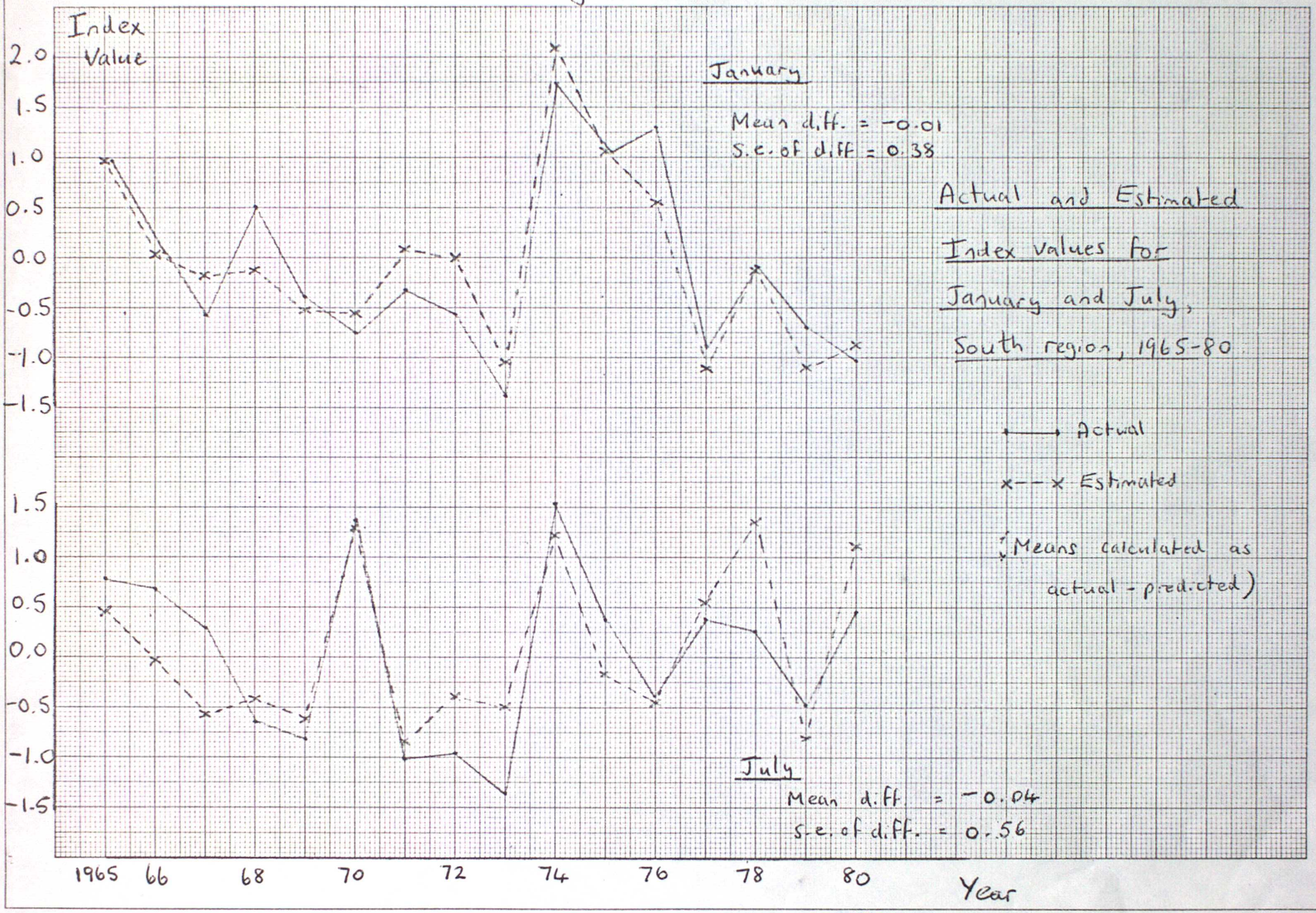
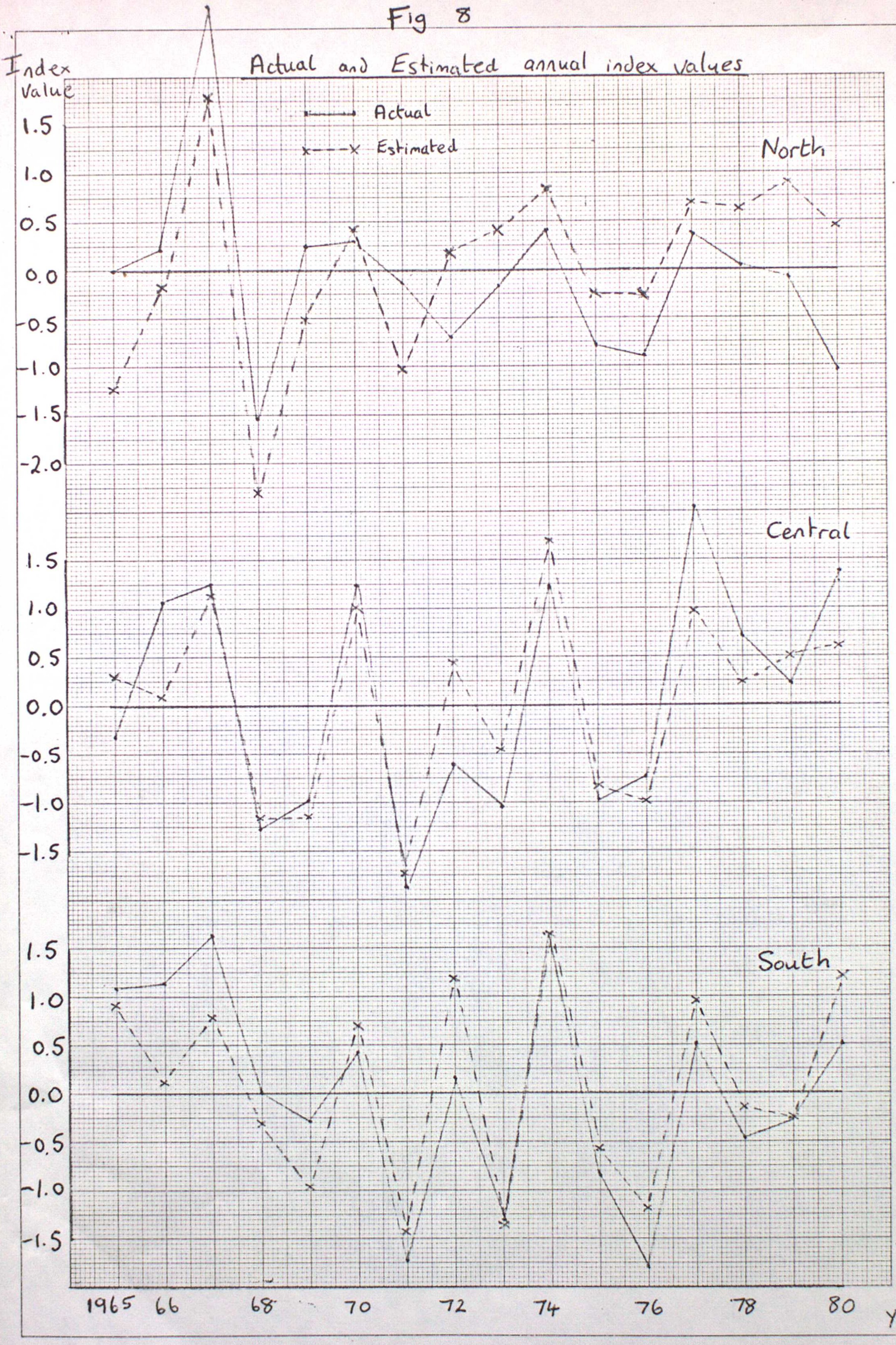

Index Value
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
January
Mean diff. = -0.01
s.e. of diff = 0.38
Actual and Estimated Index values for January and July, South region, 1965-80
Actual
Estimated
(Means calculated as actual - predicted)
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
July
Mean diff = -0.04
s.e. of diff. = 0.56
1965
66
68
70
72
74
76
78
80
Year

Fig 8



Actual and Estimated annual index values
Index Value
Actual
Estimated
North
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
Central
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
South
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
1965
66
68
70
72
74
76
78
80
Year

Fig 9

Estimated annual index values.

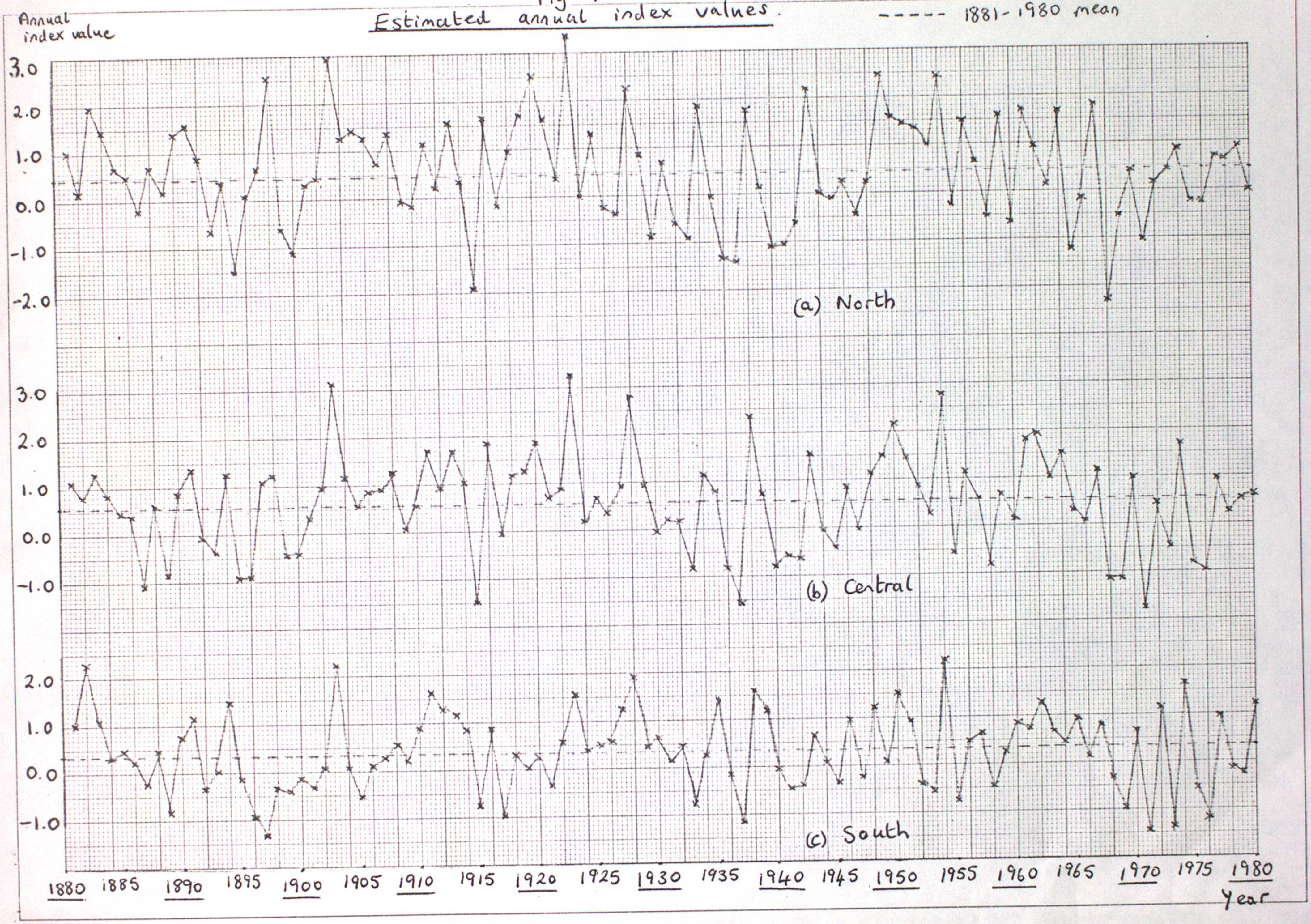


Table 1

Adjustments applied to homogenise flow indices over the period 1881-1980

Monthly flow indices were multiplied by the specified amounts (hyphen indicates no adjustment):

Period	Amount
1881 - 1898	-
1899 - 1939	1.09
1940 - 1948	-
1949 - 1959	1.09
1960 - 1965	1.20 *
1966 - 1980	-

* Comparison of annual flow index values (AFI) against annual values of I_s for 1965-1980 and a time series plot of AFI for 1960-1980 suggested that the adjustment of 1.25 given in Jenkinson and Collison's paper for the period 1960-65 is too high for the present application. The value of 1.20 was therefore used instead.

Table 2

Regression equations for estimates of monthly indices

Region	Equation	Standard error of residuals	Multiple correlation coefficient (R^2)
North	$\hat{I}_N = 0.25 \times G_2 + 0.63 \times G_3 - 0.13 \times G_6$	0.39	0.77
Central	$\hat{I}_C = -0.11 \times G_1 + 0.69 \times G_3 + 0.18 \times G_6$	0.39	0.76
South	$\hat{I}_S = 0.41 \times G_5 + 0.34 \times G_6$	0.48	0.69

$G_1 \equiv 60°N\ 5°W$ $\quad$ $G_4 \equiv 55°N\ 5°E$ (not used in these equations)

$G_2 \equiv 60°N\ 5°E$ $\quad$ $G_5 \equiv 50°N\ 5°W$

$G_3 \equiv 55°N\ 5°W$ $\quad$ $G_6 \equiv 50°N\ 5°E$

Table 3a

Windiest Averages Over The Period 1881-1980

	NORTH		CENTRAL		SOUTH	
	Year	Value	Year	Value	Year	Value
Jan	1916	2.66	1916	2.10	1937	2.18
Feb	1903	3.70	1903	3.93	1903	2.98
Mar	1967	2.11	1903	2.09	1903	2.59
Apr	1949	2.62	1947	2.32	1947	2.11
May	1956	2.30	1964	1.94	1972	1.35
Jun	1923	3.72	1923	3.28	1882	3.14
Jul	1928	1.53	1954	2.17	1954	2.46
Aug	1940	2.83	1891	2.81	1891	3.35
Sep	1950	2.03	1950	2.38	1954	2.22
Oct	1934	2.25	1934	1.93	1891	2.38
Nov	1888	3.10	1888	3.25	1881	2.76
Dec	1974	1.85	1974	2.30	1929	2.65
Winter	1881-82	2.77	1902-03	4.23	1902-03	3.35
Summer	1919	4.28	1923	3.88	1882	3.97
Annual	1923	3.34	1923	3.26	1882	2.27

Table 3b

'Quietest' Averages Over The Period 1881-1980

	NORTH		CENTRAL		SOUTH	
	Year	Value	Year	Value	Year	Value
Jan	1881	-1.47	1881	-1.60	1953	-2.09
Feb	1942	-2.16	1917	-2.01	1891	-1.96
Mar	1929	-1.35	1929	-1.64	1946	-1.40
Apr	1974	-2.28	1974	-1.85	1956	-1.68
May	1977	-1.52	1940	-1.51	1978	-1.60
Jun	1895	-1.92	1895	-2.56	1895	-1.94
Jul	1968	-1.26	1955	-1.45	1901	-1.98
Aug	1947	-1.51	1937	-1.56	1937	-1.55
Sep	1894	-1.81	1972	-1.68	1971	-1.53
Oct	1914	-2.04	1937	-2.00	1978	-1.49
Nov	1882	-2.46	1942	-3.17	1934	-2.93
Dec	1890	-1.77	1890	-1.67	1890	-1.61
Winter	1976-77	-1.72	1887-88	-2.00	1952-53	-1.82
Summer	1968	-2.44	1971	-2.33	1976	-1.93
Annual	1968	-2.30	1971	-1.74	1971	-1.44

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TABLE 4

Monthly indices averaged over the three regions, 1881–1980

(* indicates relatively large regional differences)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1881	-1.5	-0.4	0.0	0.4	0.1	1.3	0.5	1.3	-0.9	0.7	2.6	-0.4
1881	-0.1*	0.8*	0.6	0.3	0.1	1.8*	1.2*	2.0*	-0.6	-0.3*	-0.4*	-1.0
1883	0.8	2.1	0.4	0.0	0.5	-1.1	0.4	0.8	0.2	0.8	0.6	-0.2
1884	1.0	2.3	0.1	-0.9	0.8	-0.8*	-0.2	0.0	0.4	0.8	-0.9	0.4
1885	0.1	1.2	-0.4	-0.1	0.6	0.1	-0.4	0.4	0.7	0.6	-0.6	-0.3
1886	0.2	-1.2	0.3	0.5	-0.2	0.3	1.0	0.8	0.3	0.1	-0.6	-0.3
1887	0.0	0.5	-1.1	-0.3	0.2	-0.8	0.6	0.6	-0.2*	-0.1	-1.1	-0.3
1888	-0.7	-0.8	-0.4	0.4	1.2	0.1	0.2	1.2	-1.2	-0.2	2.7	-0.5
1889	-0.7*	1.6	-0.6	0.3	-0.7	-1.4	-0.3*	1.6	-0.2	-0.4	-1.0*	-0.2
1890	1.5	-0.6	0.3	0.0	0.3	1.2	1.2	0.9	0.4	0.1	-0.1	-1.7
1891	-0.3	-0.8*	0.3	-0.8	0.2	0.9*	0.3	2.7	1.3	1.6*	-1.3	0.6
1892	0.4	0.6	-1.0	-0.8	0.1	0.1	0.2	0.8	0.8	-0.4	-0.5	-1.0
1893	-0.7	0.8	-0.4	-1.3	-0.3	-1.2	0.0	1.3	0.2	-0.3	-0.1	0.7
1894	1.3	2.7*	0.3	-0.5	0.5	0.1	-0.2*	1.1	-1.5	-1.2*	0.8	0.4
1895	-0.8	-0.4	-0.3	0.1	-0.4	-2.1	0.2	0.8	-0.6	-0.4	0.6	0.4
1896	-0.8	-0.2*	0.5	0.0*	-0.8	-0.5*	-0.4	0.9	1.0	0.2	-1.5	-0.4
1897	-0.4	0.2	0.9*	0.5	1.4	0.0	0.2	1.7*	0.4	-0.4	-1.1	0.5
1898	-0.6*	2.2*	-0.5	0.1	0.4	0.3	0.0	1.5	-0.3	0.0	-0.7	1.0
1899	0.0*	0.3	-0.8	0.4	-0.6	-1.7	-0.2	0.3	0.8	-0.1	0.9	-1.2
1900	0.3	-0.7	-0.9	-0.3	0.9	0.1	-0.3	0.0	-0.2	-0.3	-1.2	0.8
1901	1.0	-1.7	0.3	0.5	-0.5	1.2*	-1.1*	0.8	0.8	-0.1	-1.2	0.3
1902	0.1	-0.2	-0.2	0.0	0.9	0.8	-0.1	-0.4	0.0	-0.5	0.6	0.6
1903	1.0	3.5	2.0	0.3	0.3	0.4	0.0	1.8	1.3	0.3*	-0.3	-0.7
1904	0.9	0.2	-0.4	1.8	0.6	1.7	-0.2	0.6	0.0	-0.5	-1.0	-0.8
1905	1.0*	1.1	0.5	0.2	-0.2	-0.1	-0.8*	0.3	0.6	-0.3	-1.1	0.3*
1906	1.4	1.0	0.7	-0.3	0.7	-0.5	0.1	0.5	-1.0	-0.3	0.1	0.1
1907	0.2	1.1*	0.4	0.2	0.6	2.1	-0.4	1.3	-0.9	-0.7	-1.9	0.2
1908	0.5	1.7	-0.3	-0.2	0.4	0.1	-0.4	0.9	0.6	0.1	0.2	0.0
1909	0.5*	0.0	-0.7	0.2	0.5	-0.4	1.3	0.6*	-1.1	1.3	-1.3	-0.5
1910	0.8	2.3	-0.1	0.0	0.3	-0.6	0.5*	-0.1*	-0.9	0.0	-0.9*	0.5
1911	-0.3*	1.4	-0.1	0.7	-0.1	1.0	0.2	0.8	-0.2	-0.2*	1.3	0.8*
1912	-0.5	0.3	0.6*	0.2	-0.7	0.6	0.0	0.6*	0.4	0.5	0.0	1.1
1913	0.9	0.5	1.5	1.1	0.9	0.8	-0.4	-0.7	-0.5	-0.4	1.7	-0.1
1914	0.0	1.6	0.6*	0.9	0.0	-0.3*	0.2	0.2	0.5	-1.7	0.5	0.4
1915	-0.2	1.1	-1.0	0.5	-0.5	-1.5	0.0	-0.5	-0.6	-1.0	-0.5	-0.8*
1916	1.9*	1.8	-0.2	0.5	-0.8	1.6	-1.1	0.2	0.2	1.3	0.9	-1.3
1917	-0.7	-1.7	-0.1	-0.4	-0.2	-0.1	-0.6	1.2*	0.4*	1.1	0.3*	-0.7
1918	-0.1	2.7*	-0.8	-1.1	-0.7	0.6	0.2*	0.8*	0.8	0.8	-0.5	0.1
1919	-0.4	-1.2	-0.8	0.6	0.5	2.4*	-0.1	1.3*	0.8	-0.4	-0.3	1.1
1920	1.3	2.0*	0.6	0.0	0.8*	0.6*	0.7	0.1	-0.3	-0.2	0.5	-0.7
1921	0.8	-0.7	1.6	-0.1	0.0	0.4	-0.2	0.6	-0.4	-0.9	-0.1	1.1
1922	0.9	1.4	-0.3	-0.8	0.8	0.2*	1.0	0.6	-0.4	-0.5*	-0.7	0.1
1923	0.5*	1.9	-1.0	0.3	0.6	2.8*	0.5	2.0	0.7	1.7	-0.3	-0.3
1924	0.2	0.1	-1.1	-0.5	0.0	-0.4	0.5	1.3	0.9	-0.5	-0.8	1.0
1925	0.7	1.4	-0.5	0.3	0.6	0.8*	-0.3	0.6	0.8	0.1	-1.5	-0.1
1926	0.3	1.2	0.3	0.0	0.2	-0.5	0.1	1.6	-0.5	-1.0*	-0.1*	-0.8
1927	0.7	-0.3	0.1*	0.9	-0.3	0.7	-0.1	1.1	-0.1	-0.5*	0.4	-0.1
1928	1.6	2.6	-0.2	0.4	0.1	1.3	0.7*	0.4	-0.4	0.8	1.6	-0.5
1929	-1.3	0.2	-1.4	-0.6	-0.1	1.1	-0.2	0.8	-0.3*	0.5	2.1	1.9*
1930	0.8	-1.4	-1.0	0.3	-0.3	0.0	0.1	1.4*	-0.4	1.4	-0.2	-0.8

TABLE 4 (Cont'd)

Monthly indices averaged over the three regions, 1881–1980

(* indicates relatively large regional differences)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1931	-0.6	1.1	-0.4	0.3	0.3	-0.4	0.7*	0.7	-0.9	-0.1	0.6	-0.1
1932	1.1	-0.6	-0.9	1.2	0.2	-1.3	0.5	-0.8	-0.1	0.0*	0.3	0.6
1933	0.0	0.8	0.4	-0.4	-0.7	0.0	0.2	0.9*	-1.5	0.3	-1.8	-1.3
1934	1.2	0.0*	-0.2	0.5	0.7	-0.8	-0.4	1.2	1.5	1.8	-2.1*	0.2
1935	-0.5	1.9	-0.5	-0.4*	-0.5	0.7	0.3	-0.5	0.9*	1.6	0.8	-1.0
1936	-0.7	-0.3	-0.8	-0.1	0.1	-1.2	0.7*	0.0	-1.0	0.8	-1.0	1.0
1937	2.1	1.3	-0.7	-0.3	-0.9	0.4*	-0.5	-1.5	0.2	-1.7	-2.1	-1.3
1938	1.0	1.1	0.5*	-0.3	-0.1	2.2	0.0	-0.3	-0.5	1.5	1.8	0.3
1939	-0.3	1.9	0.2	0.2	-0.5	1.0	1.0*	-0.6	-0.7	0.0	1.8	-1.2
1940	-1.3	-0.6	-0.1	-0.1	-1.4	-1.0	-0.3*	1.7*	0.8	0.0	0.4	-0.4
1941	-1.1	0.5	-0.9	-0.1	-0.3	-0.6*	-0.6	1.8*	-0.8	0.0	0.1	-0.3
1942	-0.4	-1.9	-0.6	0.8*	0.4	-1.0	0.9	1.4	0.3	0.2	-2.5	0.6
1943	0.2	1.9*	-0.4	1.4*	0.4	0.8*	0.2	1.1	0.5*	0.5	-0.3	-1.1
1944	0.8	0.2	-1.1	-0.1	0.3	1.0	-0.4	-0.2	0.0	-0.2	0.0	-0.2
1945	-0.9	1.9	-0.1	-0.1	0.2	1.6	0.2	-0.3	0.1	-1.0*	-2.5	-0.2
1946	0.7	1.1	-0.9	-0.2*	0.3	1.2	0.7	0.2	1.2	-1.0	0.0*	-0.6
1947	0.3	0.1	-0.6	2.3	0.0	0.7	-0.3	-1.3	-0.1	-0.9	-0.1	-1.0
1948	-0.2*	0.7	-0.1	0.0	-0.8	0.9*	0.9	0.5	1.1	0.3	-0.5	0.4
1949	1.0*	2.2*	-0.5	1.9*	-0.2	-1.0	-0.6	0.5	-0.6	0.7	0.5	0.7
1950	-0.1	1.6	-0.2	1.1	0.0	0.0	0.5	1.9	2.2	0.5	0.0*	-0.9
1951	-0.2	0.3	-0.5	0.9	0.3*	-0.4	-0.4	1.9	0.8	-0.2	1.1	0.9
1952	0.6	-0.2*	0.3	0.2	-0.1	0.6*	0.3	0.2	0.7	1.0	-1.7	-0.1
1953	-1.1*	0.4	-0.7	-0.5	0.0	-0.5	1.0*	1.2	0.7	-0.3	1.2*	-0.7
1954	0.3	0.1	-0.1	0.0	0.8	1.0	1.9	0.7	1.7	0.6	0.7	1.3
1955	-0.7	-0.5	-0.9	0.2	0.9	0.9*	-1.2	-0.4	0.9*	-0.5	-1.2	0.3
1956	-0.5	-1.1	1.0	-1.5	1.2*	1.5	0.5	0.2*	0.2	0.4	1.0*	0.8
1957	1.4	0.1	0.1	-0.1	0.1	-1.0	0.1	1.1	1.0	0.5*	-1.0	0.1
1958	0.3	0.6	0.0	0.3	-0.3	-1.0	-0.3	0.9	0.5	0.3	-2.5	-0.8
1959	-0.7	1.2*	0.0	0.4	-0.4	1.8	-0.2	0.4	-1.2	1.1	-0.1	0.6*
1960	-0.7	0.2	0.3	1.3	0.2	0.5	0.6*	-0.3	-0.3	-0.9	0.5*	-0.6
1961	-0.1	2.0	0.5*	-1.1	0.3	0.9*	0.4	2.3	0.5	1.2	-0.8	-1.0
1962	1.1	2.8*	-1.1	0.1*	0.5	1.9	-0.2	1.7	0.1	-0.1	-1.8	0.2
1963	-0.8	-0.4	0.6	0.1	1.3	0.5	-0.1	0.1*	0.5	1.5	-0.7*	-0.4
1964	-0.2*	1.1	-0.3	0.5	1.5	0.8*	1.1	0.4	0.1	-0.7	0.2	-0.1
1965	0.4	-0.4	-0.8	0.2	0.3	0.8	-0.3	1.0	-0.4	-0.1	-0.3	-0.1*
1966	-0.3	0.7	0.3	0.4*	0.6	-0.3	0.3	-0.2	-0.6	-1.3	-0.3	0.7
1967	-0.3	1.6	1.8	0.5	0.8	-0.1*	0.0	-0.3	-0.2	1.7	-0.9	-0.3
1968	-0.1	-1.1	0.6	-0.4	-0.7	-0.4	-0.9	0.0	0.1	-0.4	-0.4	-0.7
1969	-0.6	-0.5	-0.8	0.3	-0.7	-0.5	0.3*	0.5	-0.5	0.0	-0.2	-0.7
1970	-0.5	0.8*	-0.1	0.6	0.4*	-0.3	1.4	-0.3	0.6	0.7	-0.2	-0.7
1971	-0.4	-0.2	-0.8	-1.2	-0.7	-0.1	-0.9	-0.1	-1.2	0.3	0.1	0.0*
1972	0.1	0.0	-0.2	0.7*	1.1	1.7	-0.7	0.3	-1.4	-0.3	0.0	0.9
1973	-0.8	0.4*	-0.7	0.5	0.6	-0.1*	-0.5	-0.1	-0.6	-1.2	0.4	0.1
1974	2.0	0.5	-0.9	-1.8	0.5	0.4	1.0	0.5	1.1	0.2	-0.2	1.9
1975	1.2	-0.5	-0.8	0.3	-0.2	-0.1	-0.3	-1.1	0.6	-0.2	-0.4	-0.4*
1976	1.1	0.3	0.1	-0.3	0.3	-0.7	-0.4	-1.3	0.0	0.0	-0.9	-1.3
1977	-0.7	-0.5	0.5	1.2	-0.9	-0.4	0.2	-0.5	0.9	1.2	2.1	0.1
1978	-0.1	-0.8	0.8*	-0.8	-1.4	0.6	0.9	0.4	1.0	-0.6*	0.7*	0.0
1979	-1.0	-0.3*	1.2	-0.2	-0.1	-0.6	-0.1	1.0	0.6*	0.0	0.4	0.4
1980	-1.2	-0.8	-0.3	-0.3	-0.3	0.7*	0.7	0.9	0.7	0.9	0.6*	0.9