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The Seasonal Variation of Wind Speed in the United Kingdom

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1. Introduction

In the Climatological Research Group of the Climatological Services Branch (Met Ø 3) a stochastic model is being developed to simulate time series of hourly mean wind speeds for different locations in the UK. One of the features that needs to be modelled correctly is the month-to-month (or seasonal) variation of the speed. Hence an estimate of the seasonal variation is required and this is obtained from observed data. Initially observations from Birmingham Airport (Elmdon) over the period 1961-79 were used to develop the model and the seasonal variation of wind speed is illustrated for these data in fig 1. Mean monthly speeds are shown together with corresponding 95% confidence limits. An unexpected result was that October produced the lowest monthly mean - it was anticipated that July or August would yield the minimum. Fig 2 displays mean monthly speeds for Manchester Airport (Ringway) over the same period. It is seen that for Ringway, July gives the lowest value. These results suggest that a 19 year record may still be too short to estimate all the necessary features of the seasonal variation of wind speed for the UK.

2. Background

On a monthly time scale, wind speeds in any one year attain their maximum and minimum over a much wider range of months than usually occurs for other meteorological parameters such as temperature or sunshine. In many respects, monthly mean wind speeds possess similar statistical properties to monthly mean rainfall amounts. The variation of wind speed through the complete year also varies considerably from one year to the next. This means that a greater number of years are required to determine the seasonal variation of wind speed than for temperature or sunshine. Substantial spatial differences in relative wind speed can also occur, even for monthly means, and so caution is necessary if data from one station is used to infer seasonal variation over a wide area.

To illustrate the diversity of results obtained for different periods and places a small selection of statements made by various authors is presented here: Lacy (1977), writing in general terms about wind speed in Britain, states that "the highest mean wind speeds generally occur in January and the lowest in July although at some stations in England there seems to be a tendency for March to be the windiest and August or even September the quietest". Shellard (1976) concludes, from plots of the seasonal variation of wind speed at five UK stations between 1961 and 1970, that "the highest average speeds usually occur in one of the months November to March, most commonly March and the lowest in one of the months June to September, usually July". Chandler (1965), summarising a table of mean monthly speeds at Kew for 1927-56 comments that "February is clearly the windiest month and August the calmest".

The following sections consider the spatial differences in the seasonal variation by examining the changes in magnitude of an index devised for this purpose. The long term seasonal variation is studied by recourse to monthly mean speeds derived from surface pressure gradients.

3. Index of Seasonal Variation

During the analysis of the seasonal variation of wind speed it became clear that an objective measure of the variation was desirable. Walsh and Lawler (1981) have devised a seasonality index for rainfall viz.

$$I_R = \frac{1}{\bar{A}} \sum_{i=1}^{12} \left| \bar{x}_i - \frac{\bar{A}}{12} \right|$$

where $\bar{x}_i$ is the mean rainfall of month i

and $\bar{A}$ is the mean annual rainfall.

The derivation of I_R assumes, as a starting point, that rainfall falls equally in each month and the magnitude of I_R indicates how far this assumption is from reality. For wind speed the corresponding starting point was taken to be that the speed varies sinusoidally through the year with a maximum in January and minimum in July. This assertion is justified by results given in section 5 below.

An index of seasonal variation I_W has therefore been defined as

$$I_W = \frac{10}{R} \sum_{i=1}^{12} \left| \bar{x}_i - E(\bar{x}_i) \right|$$

where the 10 is introduced simply as a scaling factor,

$\bar{x}_i$ is the mean wind speed of month i,

R is the range of the $\bar{x}_i$ values,

and E($\bar{x}_i$), the "expected" speed, is given by

$$E(\bar{x}_i) = \bar{x}_{MIN} + \frac{R}{2} \left\{ 1 + \sin\left(\frac{2\pi(i-1)}{12} + \frac{\pi}{2} \right) \right\},$$

$\bar{x}_{MIN}$ being the minimum of the $\bar{x}_i$ values.

Note that for January ($i=1$), E($\bar{x}_i$) = $\bar{x}_{MIN}$ + R

and for July ($i=7$), E($\bar{x}_i$) = $\bar{x}_{MIN}$

I_W is dimensionless and is independent of the range. This is shown in the appendix. Its minimum value is zero, in which case the seasonal variation follows a pure sinusoid with maximum and minimum in January and July respectively. Its maximum value equals 97.3 i.e. approximately 100. Large values indicate that the highest and lowest monthly speeds occur at anomalous times of the year and/or the variation through the year is markedly non-sinusoidal. The calculation of I_w for Elmdon mean monthly speeds averaged over 1965-79 is illustrated in the appendix. With the aid of a pocket calculator its value can be obtained in less than five minutes.

4. Seasonal variation for 1965-79

Mean monthly speeds for the period 1965-79 were computed for 17 stations in the UK having almost complete records for this period and whose observations are considered to be reasonably homogeneous. (The 15 year period was the longest that could be used without significantly reducing the number of stations available). The locations of the stations are shown in fig. 3. Observations from Honington are not available for before October 1969 and so data for Mildenhall (only 25 km from Honington) has been used to supplement this record for earlier years.

An examination of the mean monthly speeds revealed that the month giving the lowest speed was August at all stations except Boscombe Down, when it was July and Fort Augustus, where, oddly, it was February. The month giving the highest value is shown in fig. 4. March is the month which occurs most frequently but for some stations in the west and extreme north months earlier in the winter produce the maximum.

The value of I_w (defined in the previous section) was calculated for each station. The results are displayed in fig. 5. An anomalous high value is immediately evident for Fort Augustus, whose site is in a relatively sheltered valley position in Glen Mor. Despite its unusual seasonal variation, the time series of 180 monthly mean speeds between January 1965 and December 1979 for this station correlates quite satisfactorily with corresponding time series for neighbouring stations. Apart from Fort Augustus, the highest values of I_w tend to occur in eastern areas of the UK and the lowest towards the south-west and extreme north.

Fig. 6 shows the seasonal variation of wind speed for four stations giving a wide range of I_w values. Examination of the differences between the observed and "expected" means for each month at all 17 stations indicated that in general the stations with comparatively large values of I_w had February and October means significantly lower than "expected" with March to May means higher than "expected".

For the next part of the analysis Fort Augustus was omitted since its seasonal variation is so markedly different from that of the other stations. Standardised anomalies of the mean monthly speeds were calculated for each station. This was carried out so that means of the monthly values could be computed over different stations without the results being biased towards stations having a large annual range. Means of the standardised anomalies were determined for:

(i) coastal stations in the west and north (Mount Batten, Valley, Fleetwood, Aldergrove, Prestwick, Benbecula and Kirkwall);

and (ii) all other stations.

These categories were fairly arbitrarily chosen but have been based to some extent on the results of fig. 5. The seasonal variation of wind speed for (i) and (ii) is displayed in fig. 7. None of the differences in the monthly values is statistically significant at the 5% level (because the 95% confidence limits for the two categories would overlap for all months); however it is of interest that for the west and north coastal stations the standardised speed tends to be lighter in spring and stronger in autumn and early winter compared to that for the other stations. A similar analysis for

(i) stations in the central and northern UK;

(ii) stations in the south of the UK;

gave results very similar to those described above, if one reads "central and northern" for "west and north coastal" and "south" for "others". However in both cases if data from another period had been used the results may have been different.

5. Seasonal Variation for 1881-1980

In the introduction it was suggested that a 19 year period may still be too short to estimate accurately the necessary features of the seasonal variation of wind speed. Since the Meteorological Office holds few anemograph records which are of longer duration than this, a different form of data had to be found to study the long term seasonal variation.

The Synoptic Climatology Branch of the Office possesses grid point daily wind speeds derived from surface pressure gradients at 00Z or 12Z for 1881 onwards. The six grid points closest to the British Isles were used for this analysis - they are shown in fig 8. The values are equivalent to geostrophic speeds at 55°N 5°W and are approximately geostrophic elsewhere. Monthly means of these observations were constructed with a view to studying the seasonal variation over the periods 1965-79 and 1881-1980. The speeds are not homogeneous through the 100 year period because they were obtained from different sources using different methods of analysis. Corrections have therefore been applied to the monthly means to improve the homogeneity. The details of this are omitted since any discontinuities do not affect the relationship between speeds for different months in the same year.

Curves showing the mean monthly speeds over the period 1965-79 for the six grid points are given in fig 9. The shape of the curves are similar to those presented in fig 7 for the UK regions over the same period. Thus the seasonal variation in grid point speeds can be considered satisfactory indicators of the seasonal variation over land. Mean monthly speeds for 1881-1980 were then determined for the grid points and these are displayed in fig 10. Compared to the results for 1965-79 it is seen that:

(i) the seasonal variation more closely approaches a pure sine curve;

(ii) the maximum occurs in January at all grid points whereas for the 15 year period it varied between December and January;

(iii) June, July and August give almost the same (minimum) speed. For 1965-79, August was the month most frequently yielding the minimum.

The index of seasonal variation I_w for 55° N 5° W, the nearest grid point for most of the UK, equals 11.3 for 1965-79 and falls to 8.6 for 1881-1980. This result is consistent with the above findings.

6. Summary

The seasonal variation of wind speed has been studied for 17 stations in the U.K. over the period 1965-79. March was the month that most frequently produced the highest mean speed with August the month giving the lowest value. An index of seasonal variation has been devised and this suggested that the variation through the year most closely resembled a sinusoid (with turning points in January and July) towards the south-west and extreme north of the UK. Standardised monthly speeds in the south and east were found to be higher for the spring months and lower in autumn and early winter relative to standardised speeds in the west and north. However the differences for any individual month were not statistically significant.

Mean monthly speeds derived from surface pressure gradients were calculated for the period 1881-1980 for six grid points over the UK. These indicated that averaged over many years the wind speed does in fact vary almost sinusoidally from month to month with a maximum in January and minimum between June and August.

The results obtained from this study will assist in statistical modelling of wind speed time series currently being undertaken.

7. References

Chandler, T J	1965	The climate of London. Hutchinson, London.
Lacy, R E	1977	Climate and building in Britain. HMSO, London.
Shellard, H C	1976	The Climate of the British Isles. Edited by Chandler & Gregory. Longman, New York, Chapter 5: "Wind".
Walsh, R P D & Lawler, D M	1981	Rainfall seasonality: description, spatial paterns and change through time. Weather, 36, pp 201-208.

8. Appendix

The index of seasonal variation I_W is independent of the range R of the monthly values. To show this, following the notation of section 3, express each $\bar{x}_i$ as $\bar{x}_i = \bar{x}_{MIN} + a_i R, (0 \leqslant a_i \leqslant 1)$.

Then, letting $S_i = \frac{1}{2}\left(1 + \sin\left(\frac{2\pi(i-1)}{12} + \frac{\pi}{2}\right)\right)$

we have
$$I_w = \frac{10}{R} \sum_{i=1}^{12} \left| \bar{x}_{MIN} + a_i R - (\bar{x}_{MIN} + R.S_i) \right|$$

$$= \frac{10}{R} \sum_{i=1}^{12} \left| a_i R - R.S_i \right|$$

$$= 10 \sum_{i=1}^{12} \left| a_i - S_i \right|$$

The calculation of the value of I_w is now illustrated for Elmdon 1965-79 mean monthly speeds. The observed values are given in the top row of the following table:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
$\bar{x}_i$	9.76	9.05	10.11	9.47	8.81	8.13	8.23	7.67	8.00	7.97	9.47	9.58
$E(\bar{x}_i)$	10.11	9.95	9.50	8.89	8.28	7.83	7.67	7.83	8.28	8.89	9.50	9.95
$\lvert\bar{x}_i - E(\bar{x}_i)\rvert$	0.35	0.90	0.61	0.58	0.53	0.30	0.56	0.16	0.28	0.92	0.03	0.37

R = 10.11 - 7.67 = 2.44 kn and we calculate 0.067R, 0.25R and 0.5R.

Then $E(\bar{x}_i)$ for January = $\bar{x}_{MAX}$ = 10.11
" July = $\bar{x}_{MIN}$ = 7.67
" February and December = $\bar{x}_{MAX}$ - 0.067R = 9.95
" March and November = $\bar{x}_{MAX}$ - 0.25R = 9.50
" April and October = $\bar{x}_{MAX}$ - 0.50 = 8.89
" May and September = $\bar{x}_{MIN}$ + 0.25R = 8.28
" June and August = $\bar{x}_{MIN}$ + 0.067R = 7.83

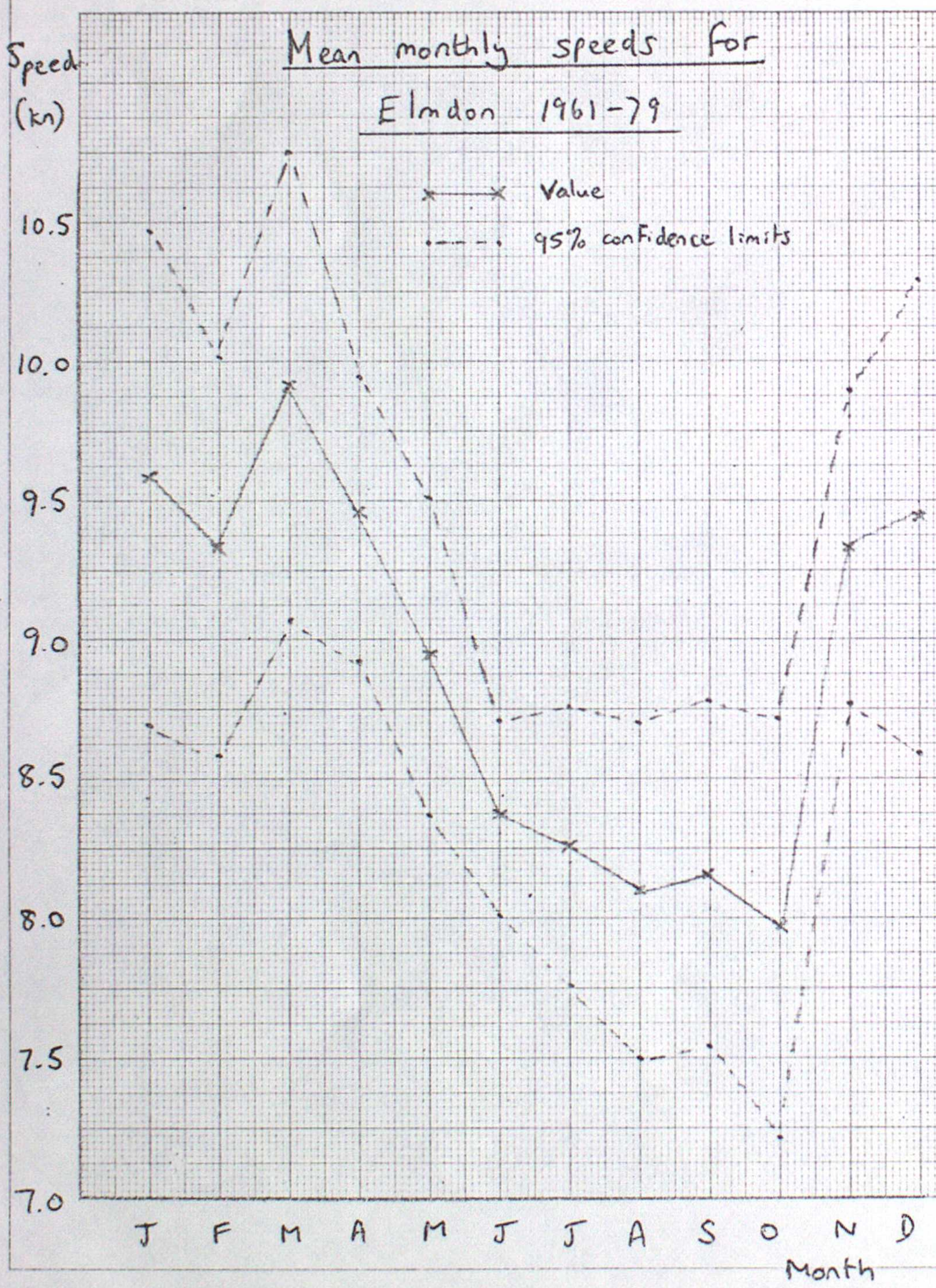
The second row of the table is thus compiled and values for $|\bar{x}_i - E(\bar{x}_i)|$ can be determined (row 3).

Then
$$I_w = \frac{10}{R} \sum_{i=1}^{12} \left| \bar{x}_i - E(\bar{x}_i) \right|$$

$$= \frac{10}{2.44} \times 5.59$$

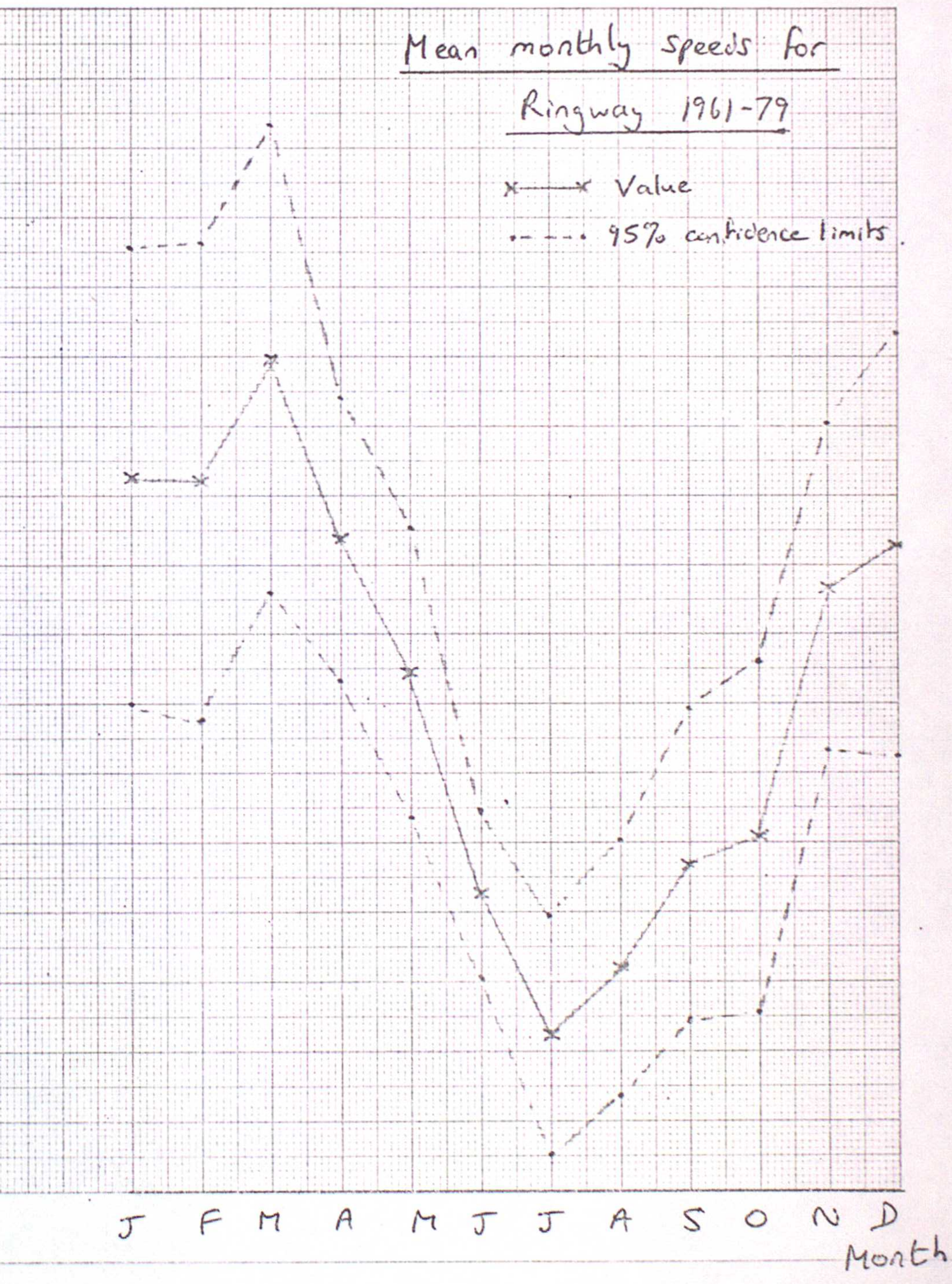
$$= 23$$ to the nearest integer.

Fig 1



Mean monthly speeds for
Elmdon 1961-79
Value
95% confidence limits
Speed (kn)
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
J F M A M J J A S O N D
Month

Fig 2



Mean monthly speeds for
Ringway 1961-79
Value
95% confidence limits
J F M A M J J A S O N D
Month

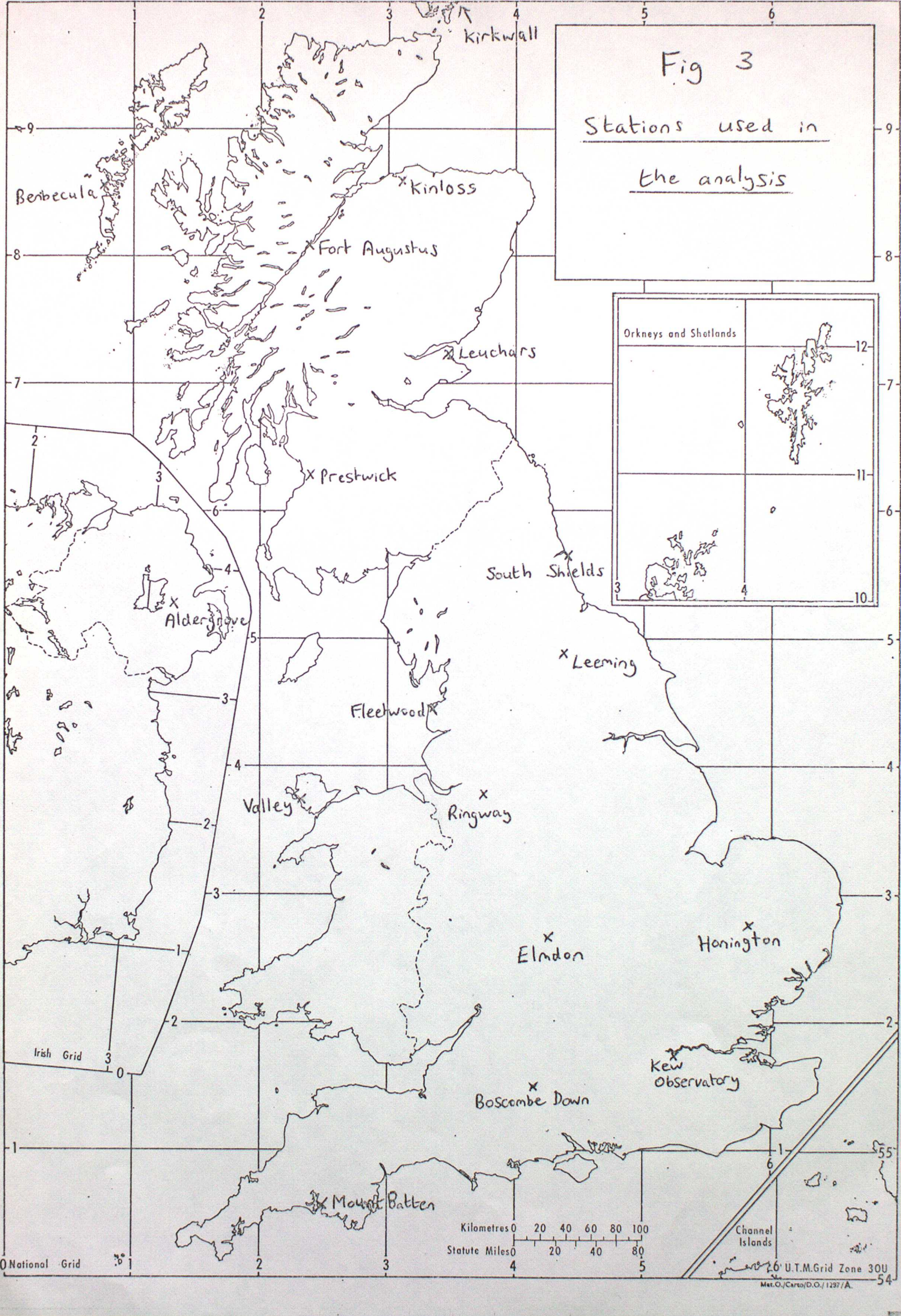


Fig 3

Stations used in the analysis

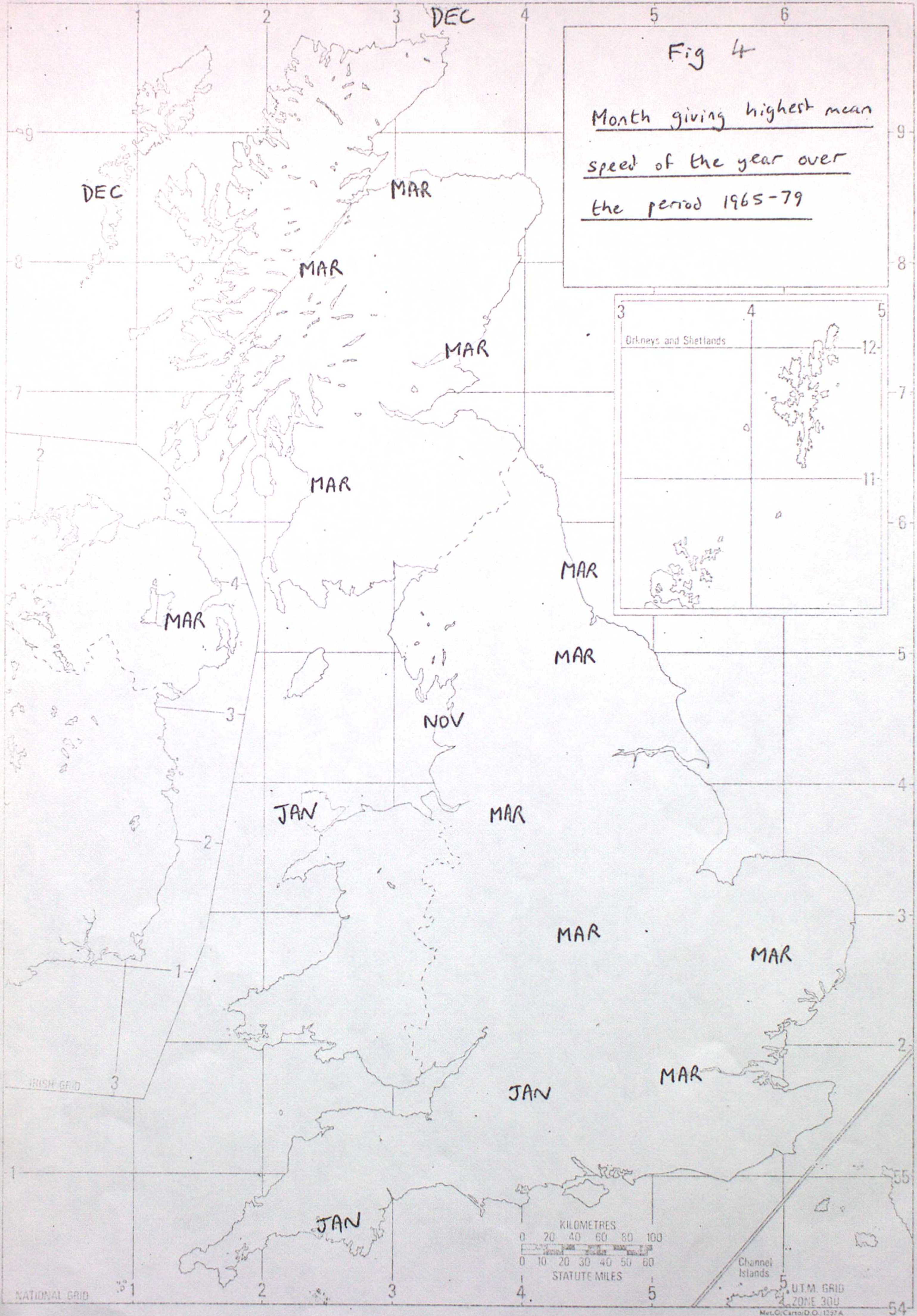


Fig 4

Month giving highest mean speed of the year over the period 1965-79

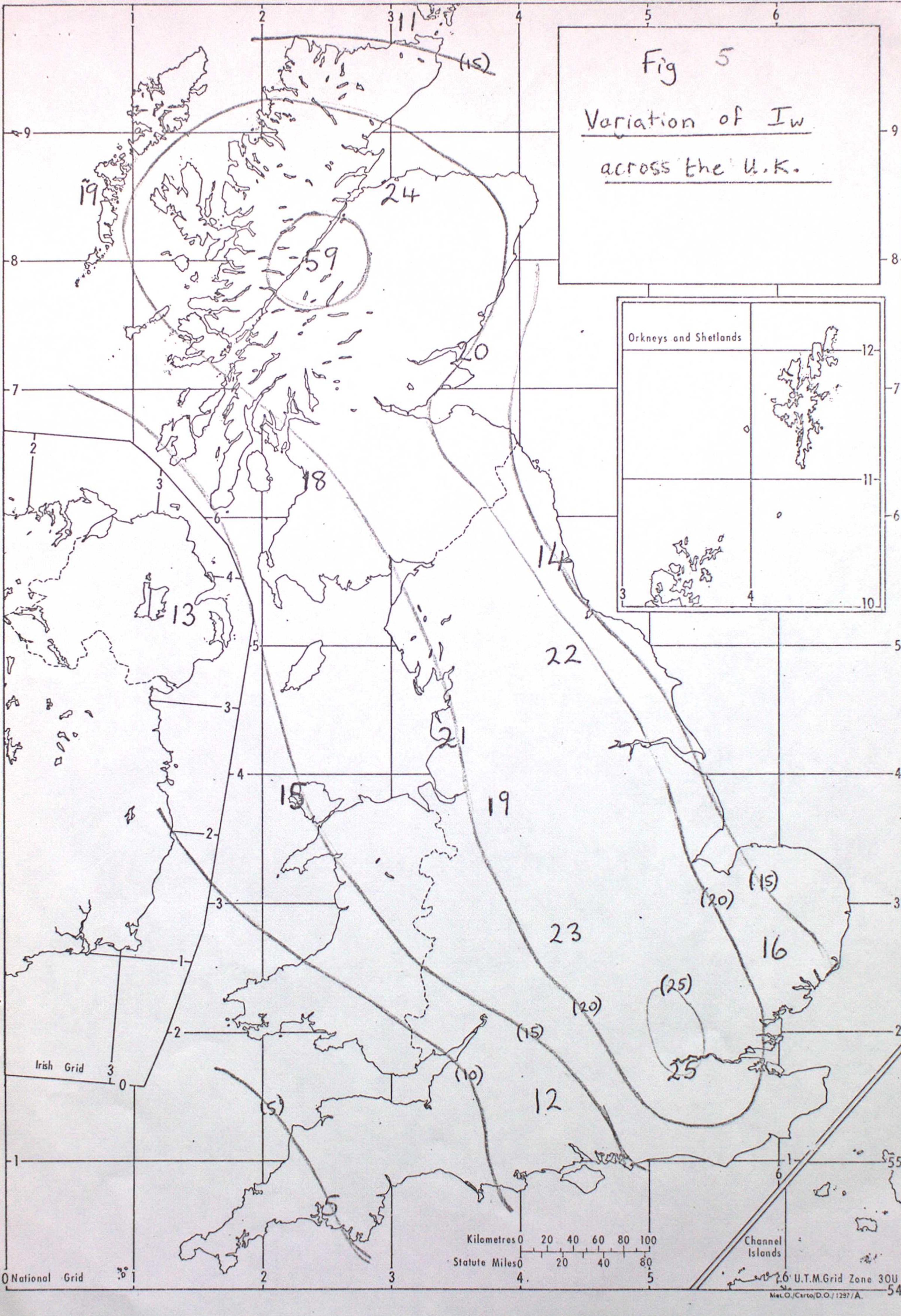


Fig 5

Variation of Iw across the U.K.

Fig 6

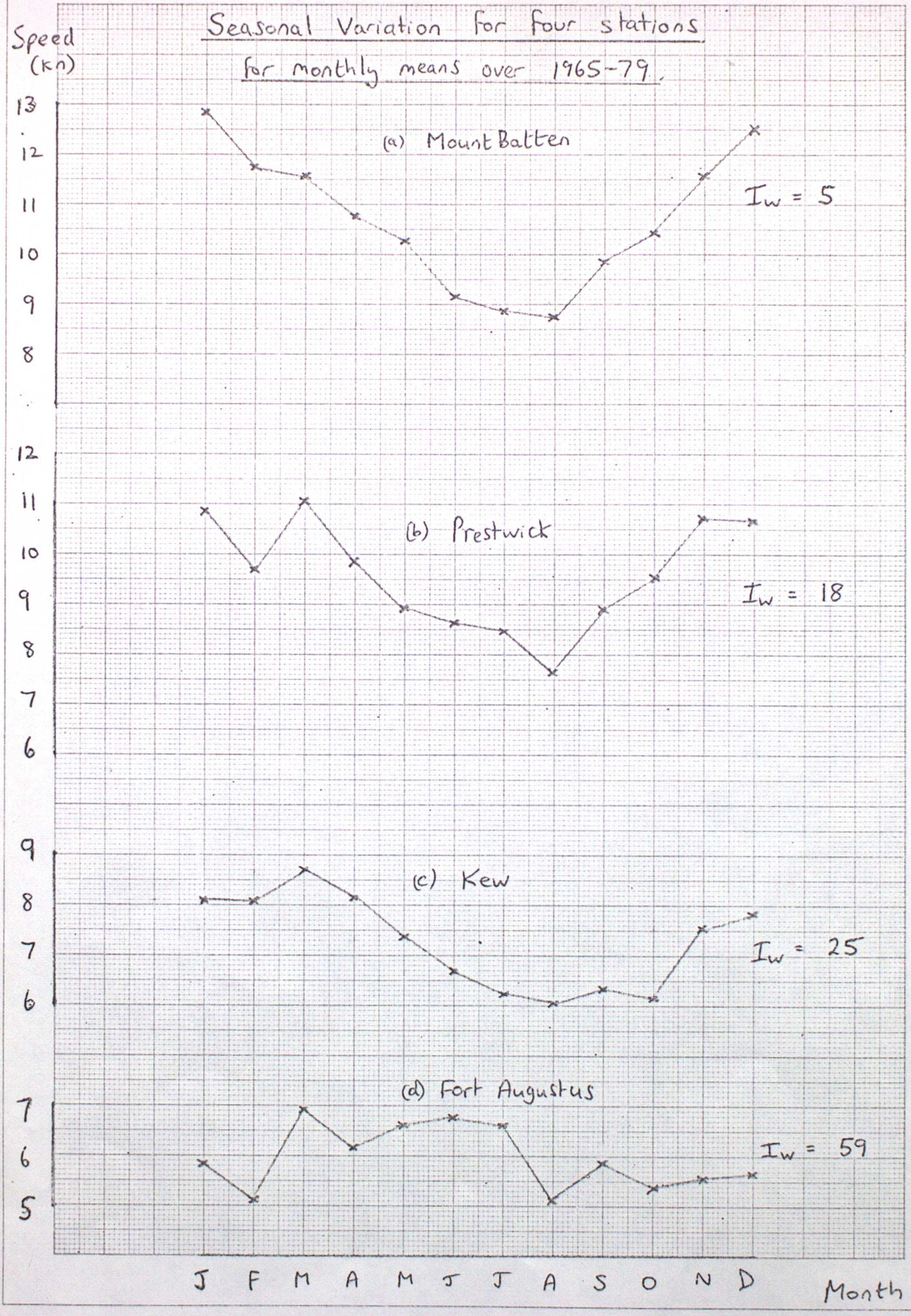

Seasonal Variation for four stations
for monthly means over 1965–79.
Speed
(kn)
13
12
11
10
9
8
(a) Mount Batten
I_w = 5
12
11
10
9
8
7
6
(b) Prestwick
I_w = 18
9
8
7
6
(c) Kew
I_w = 25
(d) Fort Augustus
7
6
5
I_w = 59
J F M A M J J A S O N D
Month

Fig 7

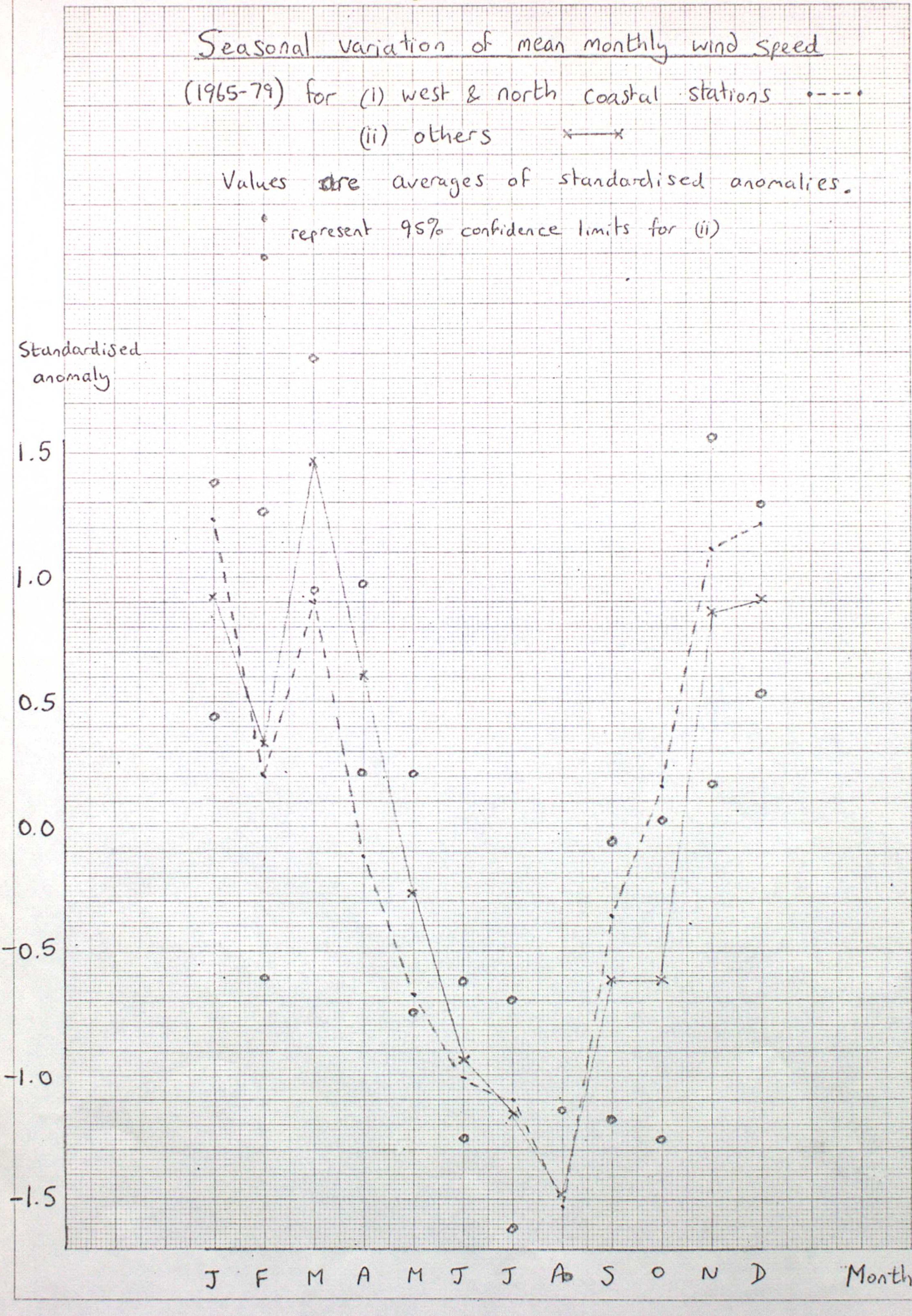
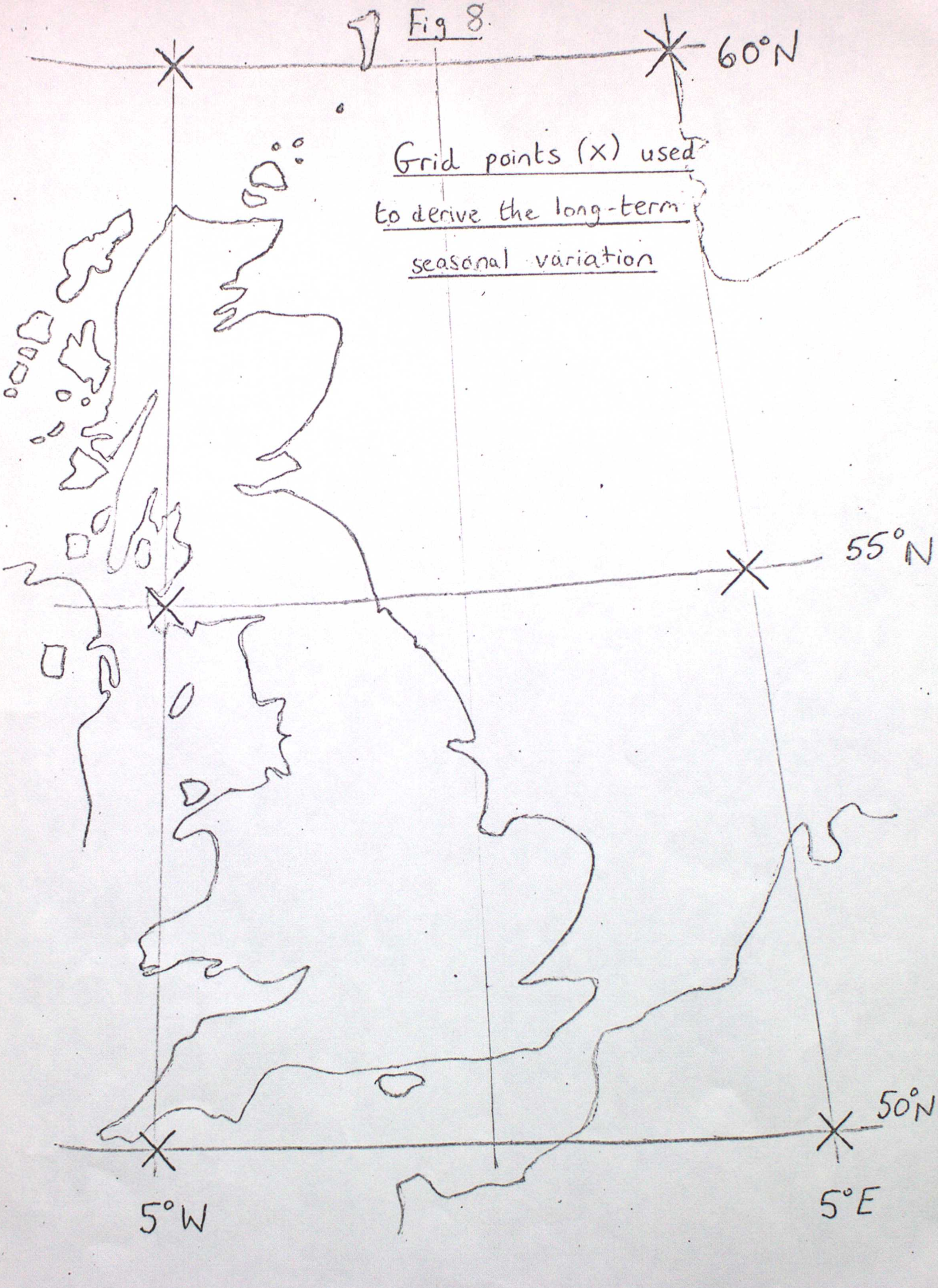

Seasonal variation of mean monthly wind speed
(1965-79) for (i) west & north coastal stations
(ii) others
Values are averages of standardised anomalies.
represent 95% confidence limits for (ii)
Standardised anomaly
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
J F M A M J J Au S O N D
Month

Fig 8.



60°N
Grid points (X) used to derive the long-term seasonal variation
55°N
50°N
5°W
5°E

Fig 9

Mean Monthly Wind Speeds 1965-79 for various grid points.

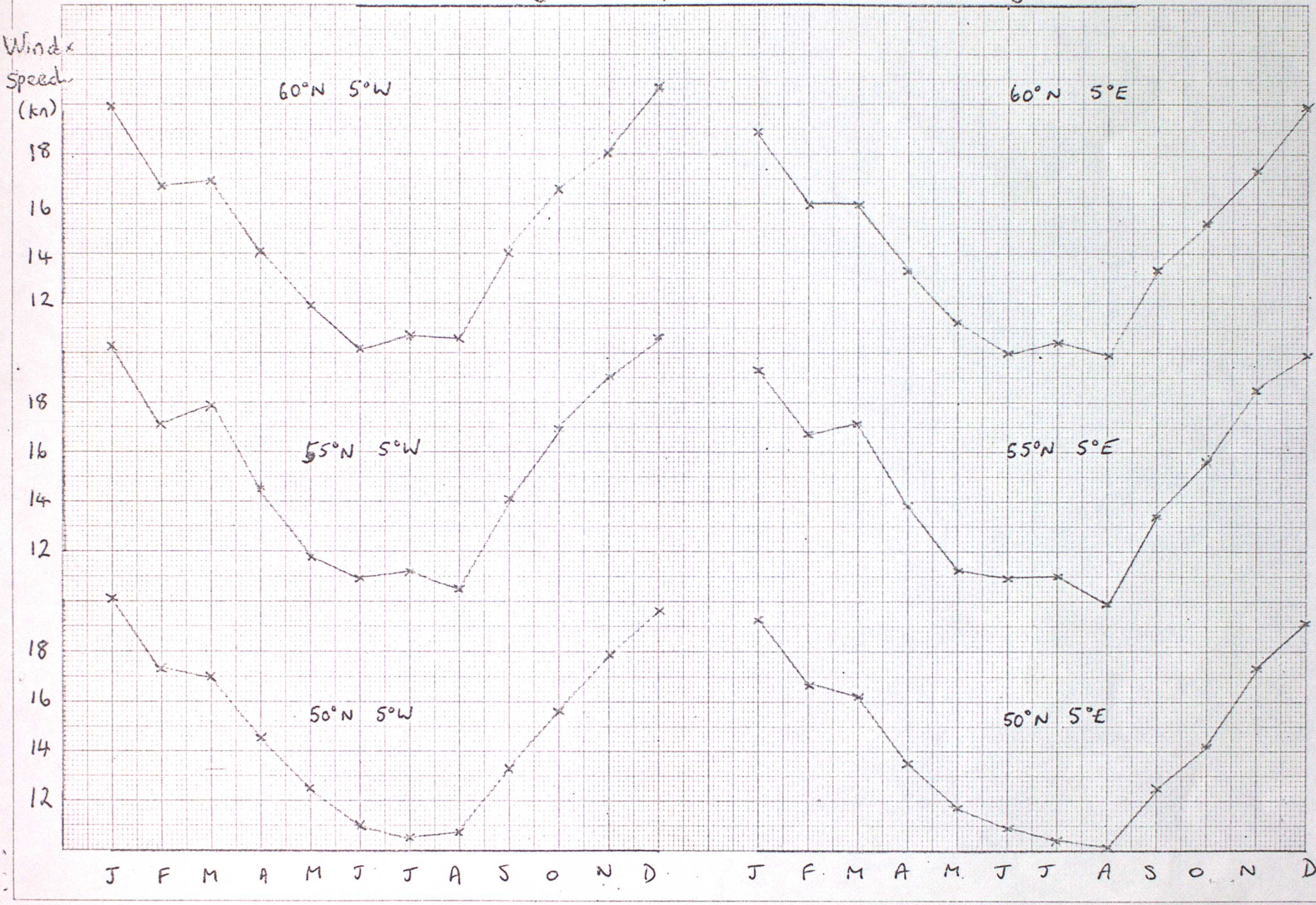
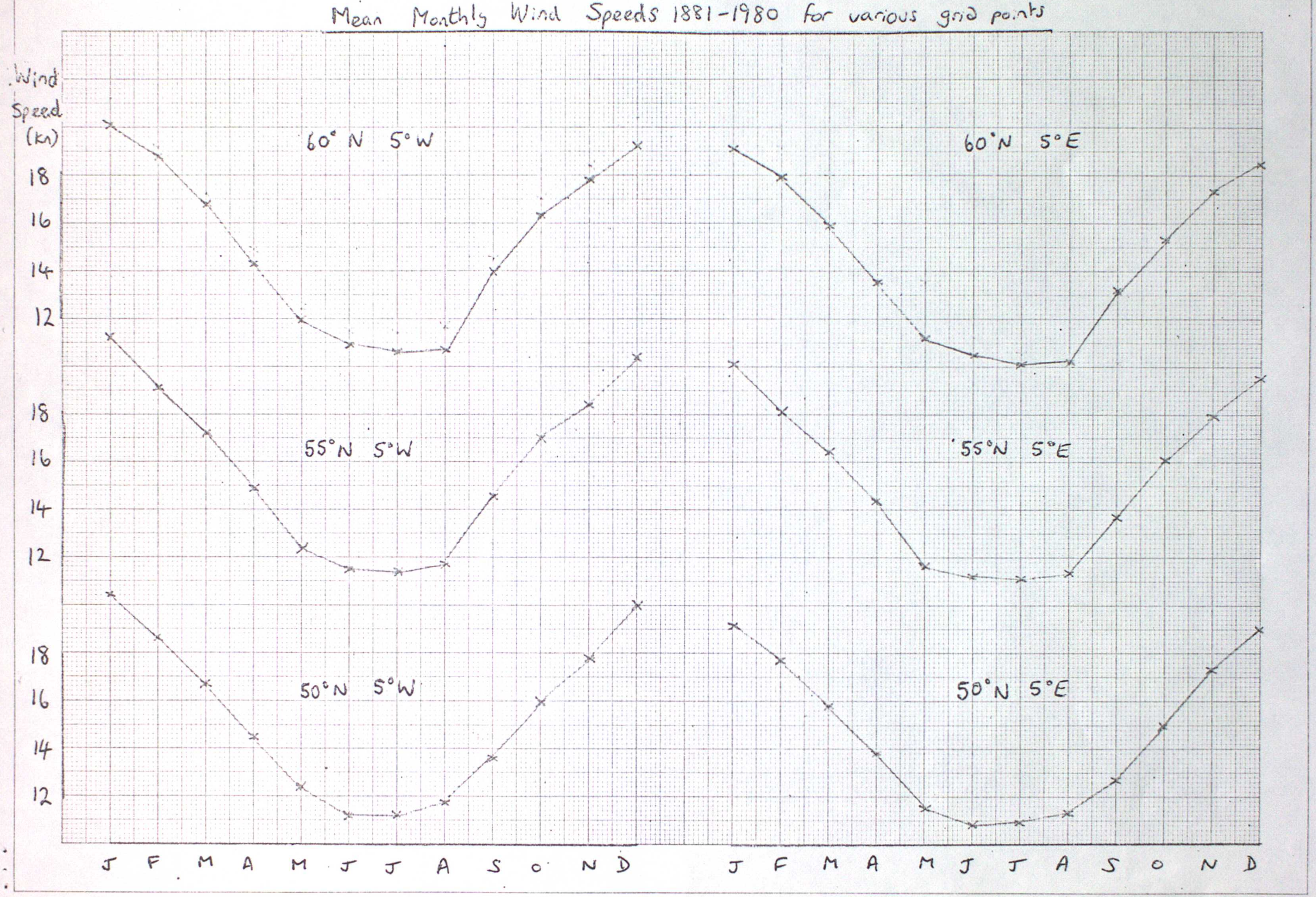


Fig 10.


Mean Monthly Wind Speeds 1881-1980 for various grid points
Wind Speed (kn)
18
16
14
12
60° N 5°W
55°N 5°W
50°N 5°W
60°N 5°E
55°N 5°E
50°N 5°E
J F M A M J J A S O N D
J F M A M J J A S O N D