LONDON, METEOROLOGICAL OFFICE.

Met.O.3 Technical Note No.23.

The diurnal range of temperature over the U.K. By TABONY, R.C.

London, Met.Off., Met.O.3 Tech.Note No.23, 1983, 31cm. Pp.[ii]+8, 11 pls. 7 Refs. Abs.p.1.

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MET O 3 TECHNICAL NOTE NO 23

THE DIURNAL RANGE OF TEMPERATURE OVER THE U.K.

by

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August 1983

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Summary

Geographical and seasonal variations in the diurnal range of temperature over the UK are examined. Variations due to differences in climate and topography are seen to change in relative importance as less common events are considered.

1. Introduction

The frequency and severity of frosts is an important aspect of climate for a wide variety of activities, especially those in the agricultural and construction industries. As the proneness to frost is very sensitive to local site details, a good knowledge of the relationships between minimum temperatures and topography is required. In this context, the word 'topography' is used in the widest possible sense to include all relevant physical factors such as aspect and slope, soil and vegetation, degree of urbanisation, distance from the coast etc.

The effects of topography on frost are best investigated when variations due to other factors, eg latitude and altitude, have been minimised. One way of doing this is to choose the diurnal range of temperature (hereafter referred to simply as the 'diurnal range') as the relevant climatic parameter. There are disadvantages in this approach. Topographic effects on maximum temperatures will be included, for instance, and in winter the largest diurnal ranges may be caused by advection rather than radiation. The lowest temperatures in winter may not be associated with large diurnal ranges, as the surface inversion present during periods of cold weather gradually increases its strength day by day. One of the main applications, however, will relate to frosts in spring, and for this purpose the diurnal range is an appropriate climatic parameter to use.

Although the average diurnal range is easily obtained from means of daily maximum and minimum, most practical applications will be concerned with more extreme events - the largest diurnal range in a month, for instance. This is a parameter which is not recorded explicitly in tabulations of meteorological data, and hence very little is known about it. As a preliminary to an investigation into relationships between diurnal range and topography, some simple analyses of the diurnal range were made, and these are presented here for their general climatological interest.

2. Creation of a data set of the highest diurnal range in a month

Daily values of 24 hour (09–09) maximum and minimum temperatures in the period 1959–79 were accessed for all stations with less than 120 months of missing data in that period. The number of stations was around 570, and their distribution is shown in Fig 1.

Daily values of diurnal range were calculated from the 24 hour maximum on day i – 24 hour minimum of day (i+1). This represented the night fall, rather than the day rise of temperature, as this is the main parameter of interest. It also has the advantage that in winter, when large changes of temperature can be caused by advection rather than radiation, sudden falls of temperature (due to advection) are less common than sudden rises. The arrangement of data into monthly blocks, however, made this arrangement inconvenient on the last day of the month, so on this day the daily rise in temperature was used instead. If any daily maximum or minimum temperature was missing, preventing the calculation of the night fall in temperature, then the day rise was used in preference to the acceptance of a missing value.

The highest diurnal ranges in a month were derived from the daily values as follows. In any month in which more than one daily range was missing, the highest value for that month was also regarded as missing. The highest daily ranges in the remaining months were then averaged over all years for each calendar month, and any values which exceeded the mean for the appropriate calendar month by more than 12°C was rejected. Prior to 1972, the original daily maximum and minimum temperatures had not been subject to any quality control procedures. Any missing values of the highest diurnal range were then estimated using the methods described by Tabony (1983).

3. The effect of climate

The relationships between topography and diurnal range will depend on the climate, and particularly on the wind and cloud. The differences in diurnal range between a valley and a hilltop, for instance, will be greater where the climate is clear and calm than where it is cloudy and windy. The influence of climate will also depend on the return period of the event under consideration. Compare, for example, the diurnal ranges at topographically similar sites in the northwest and southeast of Britain. The average diurnal range would be expected to be greater in the southeasterly location because of the smaller mean amounts of cloud and wind. The largest diurnal range recorded over a period of 20 years, however, would be expected to be similar at both locations, because in that length of time even a most disturbed climate would include some good radiation nights. The question therefore arises as to what extent, in Britain, is the highest diurnal range in a month likely to be affected by changes of climate across the UK?

A guide to the answer was obtained by examining the highest daily sunshine totals recorded in a month at around 380 stations in the UK with less than 120 missing values in the period 1959-79. The missing data were again estimated using the procedures described by Tabony (1983).

As the sunshine totals were being used as a guide to cloud amounts, they should clearly be expressed as a percent of the maximum possible, and one of the problems in this respect is that of obstructions. Although site details are documented sufficiently well to enable the effect of obstructions to be calculated, they are not held in machineable form. An alternative means of obtaining relative sunshine was therefore adopted. It was assumed that at least one day of unbroken bright sunshine would occur in each calendar month in the 21 years of data examined. The highest daily totals of sun were therefore expressed as a percentage of the highest value recorded for that calendar month in the period 1959-79.

For each station, the 21 values of highest daily sun for each month were ranked, and the median values extracted. Geographical variations in these median values, meaned over all months, are illustrated in fig 2. All the maps presented in this paper are generalised in the sense that the station values, to which the isopleths have generally been drawn, show a wide scatter due to the dependence (especially for diurnal range) on local topography. A little smoothing has been employed, but no significance should be attached to the small-scale detail. The main features, however, are well represented, and in fig 2 a decrease from around 92% on the south coast of England to less than 82% in the interior of Scotland can be seen. Seasonal variations at 10 stations are displayed in fig 3. Median values in summer are seen to be higher than in winter, and in the northwest, this seasonal variation is pronounced.

Some qualifications have to be made on the implications of these results for the diurnal range of temperature. For any given cloud amount, the amount of sunshine recorded will decrease with solar elevation, and this effect will tend to produce low values of sun in Scotland in winter. Large diurnal ranges are not necessarily associated with good visibility, and in winter, cold nights may be followed by mornings with mist or fog. However, large diurnal ranges require light winds as well as clear skies, and it seems unlikely that good radiation nights will occur much more frequently than sunny days, with or without wind. It therefore seems fair to conclude that at all times of the year, and especially in winter, most monthly maxima of diurnal range will be observed under more favourable radiation conditions in the south of Britain than in the northwest.

4. Geographical variations in diurnal range

The average diurnal range, meaned over all months, is displayed in fig 4; it is similar to the map first produced by Ashmore (1939). The main features are

(i) a general increase from northwest to southeast as the climate becomes less cloudy and windy.

(ii) Coastal gradients on the east coast which are sharper than on the west coast, where the prevailing winds are on-shore.

(iii) Coastal gradients which are also intense in the south-east, where the sunnier climate enables the potential differences between land and sea to be more fully realised than elsewhere.

The mean monthly maximum diurnal range, meaned over all months, is presented in fig 5, and shows that topography has replaced climate as the most important variable. The considerably decreased effect of the prevailing wind means that coastal gradients are limited to a few tens of km and are relatively uniform along all coasts.

The largest diurnal range observed in each month in 21 years of record, and meaned over all months, is illustrated in fig 6. Differences due to climate have been practically eliminated, and the highest values are observed near the high ground in Scotland, especially in winter. Dight (1967) points out that large diurnal ranges in Scottish glens in winter are associated with high maxima as well as low minima. Maximum temperatures rise above freezing even in the presence of snow cover. Dight ascribes this to the turbulence set up by the high ground breaking down nocturnal inversions which would persist over lower ground, especially if it were protected by more distant hills (as at Abbotsinch, for example).

One of the features of figs 4-6 is the way that, as the return period of the event increases, the diurnal range in Scotland increases more rapidly than in the south of England, especially in winter, as the prevailing climate decreases in importance and the effect of topography increases. This phenomenon can be represented by the slope of an extreme value analysis of diurnal range.

5. Extreme value analysis of diurnal range

The 21 years of monthly maximum diurnal ranges were plotted on extreme value paper using the plotting position recommended by Jenkinson (1955), namely

$$p = \frac{m - 0.31}{N + 0.38} \quad (1)$$

where p is the probability ascribed to the mth ranked of N observations. The observations do not in general lie on a straight line, but appear bounded above. Nevertheless, a straight line was fitted to the observations using a program devised by Jenkinson (1977) which gave extra weight to the more extreme observations. An example of its application is shown in Fig 7 using data from Corwen in North Wales. Use of equation (1) yields a return period of around 30 years for the largest event in a sample of 21.

As the observations selected only represent the highest values from the small samples of independent diurnal ranges available in a month, there is no question of the theory of extreme values being satisfied. Neither is there any question that fitting a linear relation to the values obtained is physically realistic. The procedures described above are used simply as a convenient means of introducing a new variable - the slope of the extreme value analyses - which describes an important feature of the climatology of diurnal range.

The slope of the extreme value analysis of diurnal range was calculated as described above, and the geographical variations of the values meaned over all months are displayed in fig 8. The large values associated with high ground in Scotland are well illustrated.

6. Seasonal variations in diurnal range

The diurnal range will increase with solar elevation; in winter the power of the sun is often unable to destroy the nocturnal inversion, whereas in summer superadiabatics can be produced. Greater equality in the length of day and night is also a factor in favour of large diurnal ranges. The net result is a seasonal variation in diurnal range which is characterised by a broad summer maximum and a sharp winter minimum. This is illustrated in fig 9, which displays the diurnal range to be expected once every 2 years. For climatological purposes the Meteorological Office has divided the UK into 10 districts, and the diurnal ranges shown in fig 9 have been meaned over the 5 stations with the largest diurnal ranges in each district. In fig 9, the districts are positioned according to their approximate geographical location, ie with North at the top of the page and east to the right. Geographical variations are seen to be small, but the difference in sharpness between the summer peak and winter trough is smaller in the North than in the South.

The slopes of an extreme value analysis were calculated as described in section 5, smoothed over a number of months using a 7 point binomial filter (see Lee, 1981), and meaned over the same stations as in fig 9. The results are illustrated in fig 10 and show that over most of Britain there are only small seasonal variations, but that in northern Scotland there is a pronounced peak in March. These results have to be interpreted in the light of the standard errors involved. The standard errors associated with the intercept (U), slope (α), and ordinal value (X) of a Gumbel distribution fitted to N observations are

$$SE\ (U) = 1.05\,\alpha / \sqrt{N}$$

$$SE\ (\alpha) = 0.78\,\alpha / \sqrt{N} \qquad (2)$$

$$SE\ (X) = \sqrt{(1.11 + 0.52y + 0.61y^2)}\ \alpha / \sqrt{N} \qquad (3)$$

(NERC, 1975, p.103). The standard error indicated in fig 10 has been calculated from equation (2) using N=21. This will be an underestimate of the error associated with the Jenkinson fit, since the weighting procedure reduces the number of independent observations used. As the values presented in fig 10 have been smoothed over a number of months and averaged over 5 stations, however, the errors obtained from equation (2) are probably close to the true values.

The standard errors are large enough to indicate that the peak in the slope in March in Northern Scotland could have occurred by chance. Nevertheless, the feature is a surprise as a maximum in winter had been expected. As discussed earlier, however, the lowest temperatures in winter are not necessarily accompanied by high diurnal ranges, and the slope of an extreme value analysis of minimum temperatures may well peak in winter. The peak in March for diurnal range may be due to the increased power of the sun in raising day maxima combined with a snow cover at higher levels to nourish nocturnal katabatics. The long record available for Braemar could be used to assess whether the March peak is real, but the data are only held in manuscript form.

The 2 year values of diurnal range were smoothed over months using a 7-point binomial filter, and these, together with the smoothed values of the slope, were used to estimate values of the diurnal range with a return period of 30 years. The results, illustrated in fig 11, show that over England and Wales, the highest values occur in the late summer, possibly because the ground is driest then. In northern Scotland, highest values occur in the spring, but the standard errors (as calculated from equation (3)), are large.

7. Conclusions

The average diurnal range of temperature over Britain is greatest in the southeast, and decreases to the northwest in response to the cloudier and windier climate. As more extreme events are considered, differences in climate become less important, and the largest diurnal ranges are likely to occur in Scotland, where the topography is more favourable for the development of extremes of temperature. Diurnal ranges tend to be smaller in winter than in other seasons, and the largest values are liable to occur between March and September.

References

Ashmore, S. E.	1939	The diurnal range of temperature and the geographical distribution of its annual variation. Q. J. Roy. Met. Soc., 65, 554-558.
Dight, F. H.	1967	The diurnal range of temperatures in Scottish glens. Met Mag, 96, 327-334.
Jenkinson, A. F.	1969	Statistics of extremes. In Estimation of maximum floods, WMO Tech Note No 98, Chapter 5, pp. 183-257.
Jenkinson, A. F.	1977	The analysis of meteorological and other geophysical extremes. Syn. Clim. Branch Memo No 58, Met Office, Bracknell.
Lee, A. C. L.	1981	Smoothing and filtering of meteorological data. Met Mag, 110, 115-132.
N.E.R.C.	1975	Flood Studies Report, Vol 1 - Hydrological Studies, Wallingford.
Tabony, R. C.	1983	The estimation of missing climatological data. J. Clim, 3.

FIG 1 - DISTRIBUTION OF STATIONS

FIG 2 - GEOGRAPHICAL VARIATION OF THE MEDIAN HIGHEST DAILY SUNSHINE IN A MONTH

Figures are expressed as a percent of the sunniest day in each calendar month in the period 1959-79, meaned over all calendar months.

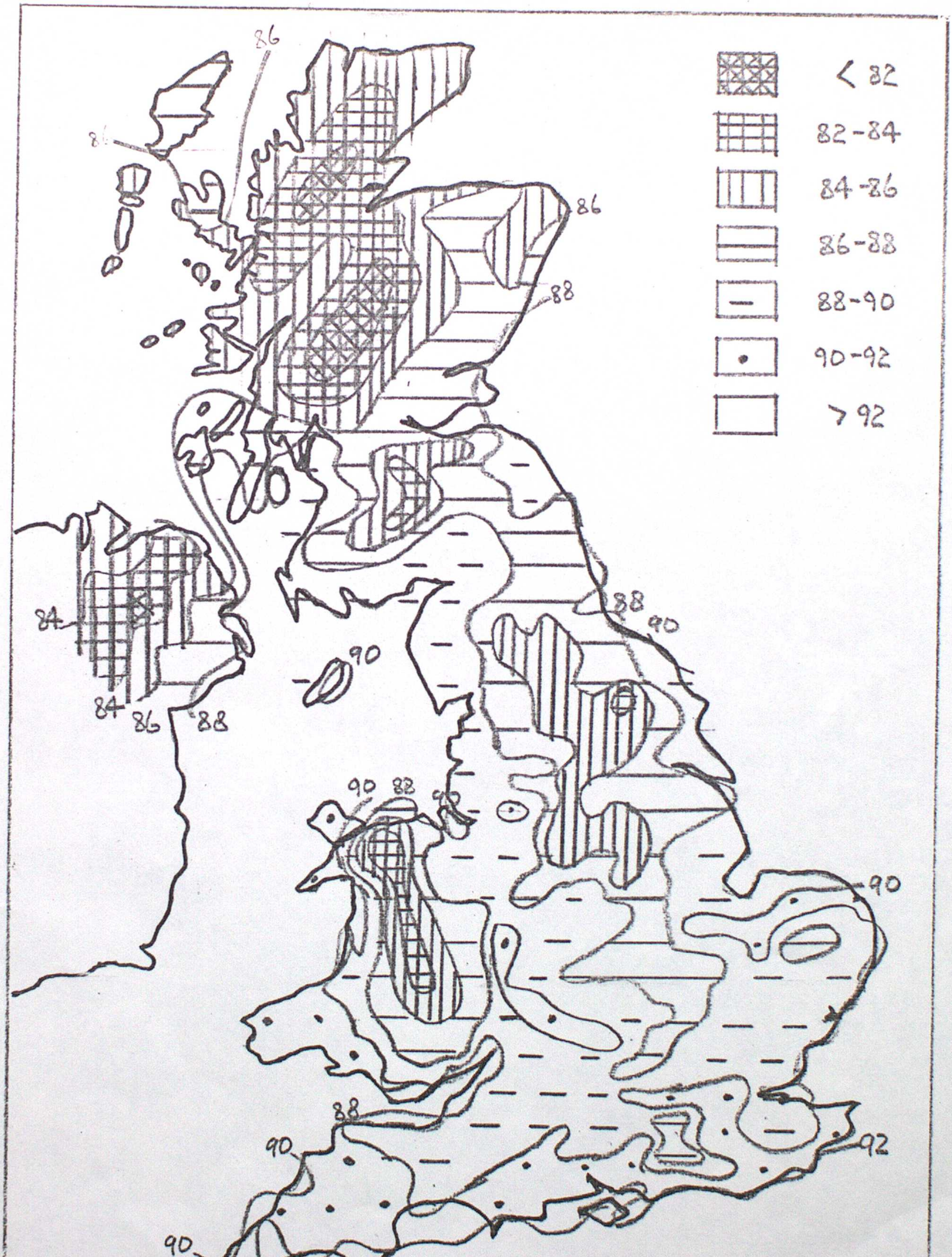


FIG 3 - SEASONAL VARIATION OF THE MEDIAN HIGHEST DAILY SUNSHINE IN A MONTH.

Figures are expressed as a percent of the sunniest day in each calendar month in the period 1959-79.

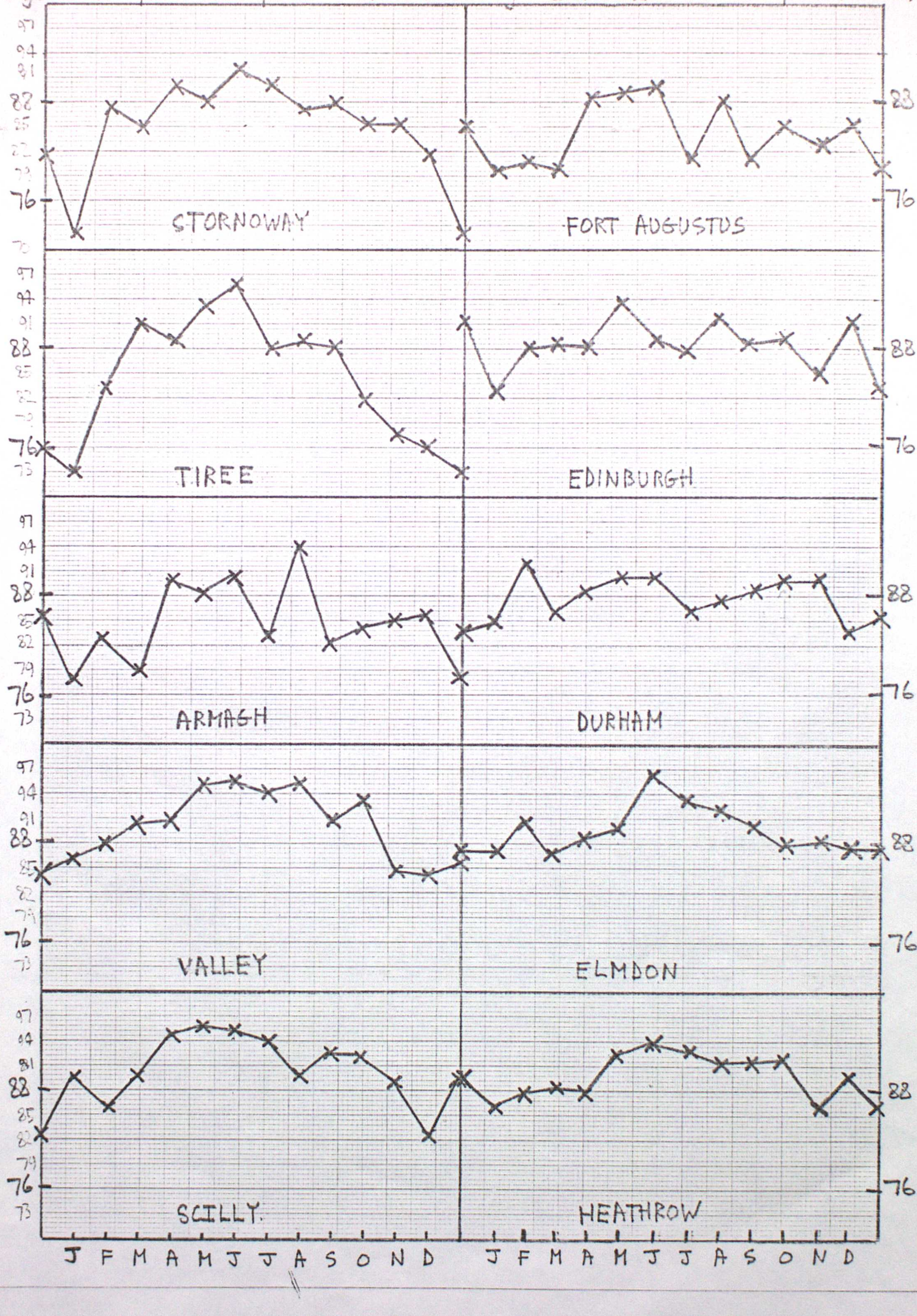


FIG4 - GEOGRAPHICAL VARIATION OF THE MEAN DIURNAL RANGE
(MEANED OVER ALL MONTHS)

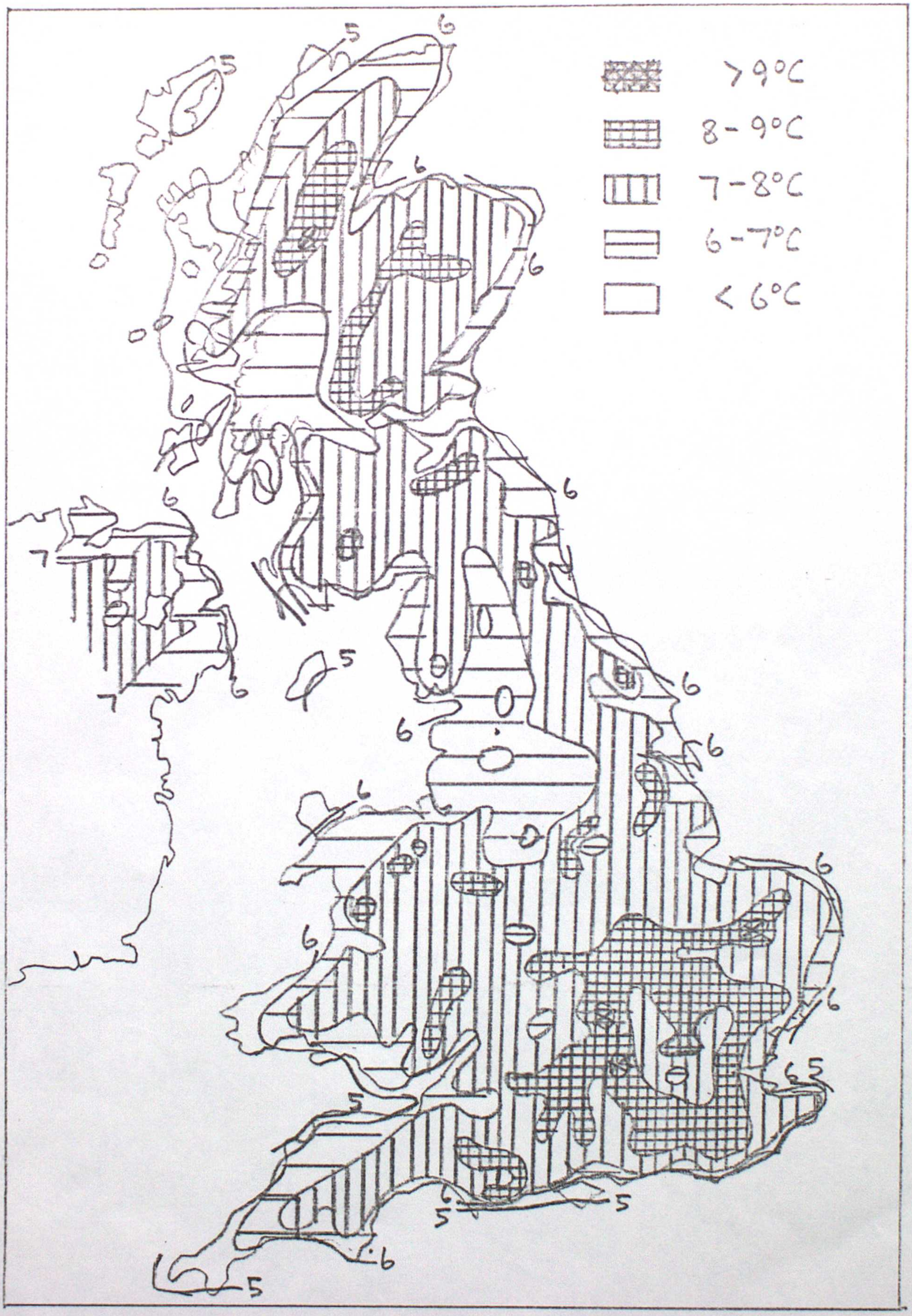


FIG 5 - GEOGRAPHICAL VARIATION OF THE MEAN MONTHLY MAXIMUM DIURNAL RANGE (MEANED OVER ALL MONTHS)

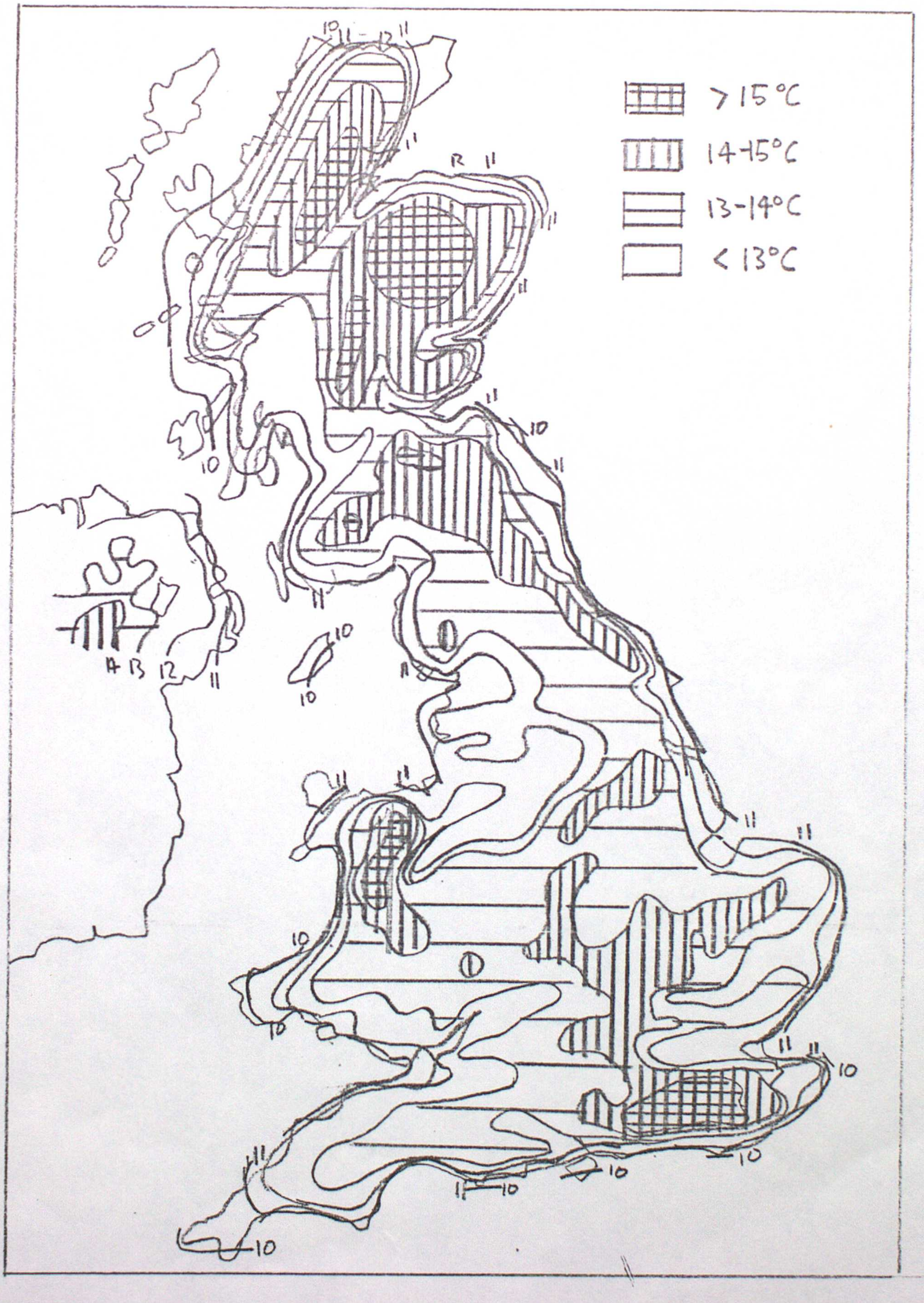
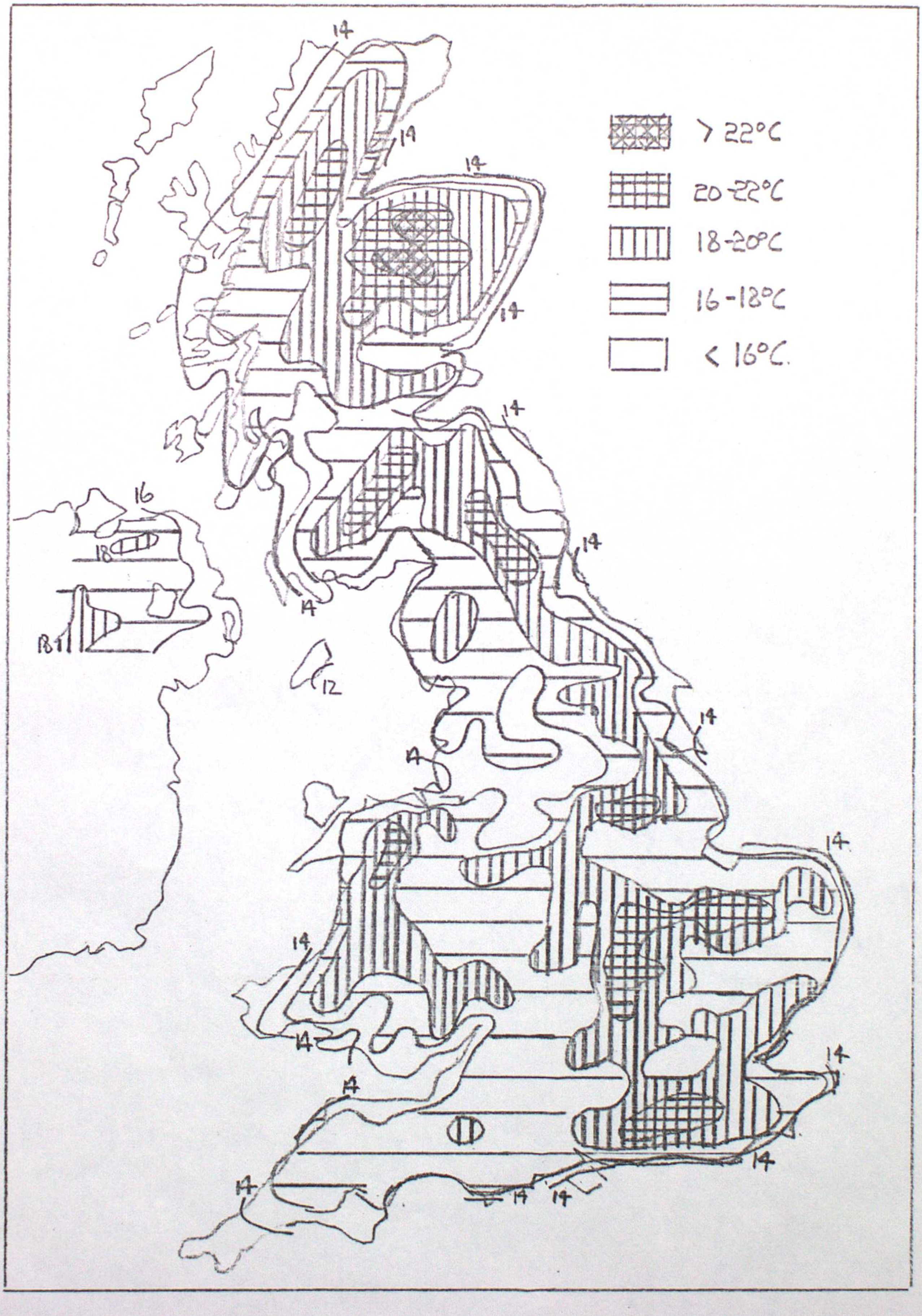


FIG 6 - GEOGRAPHICAL VARIATION OF THE HIGHEST MONTHLY DIURNAL RANGE, 1959-79 (MEAN OF ALL MONTHS)



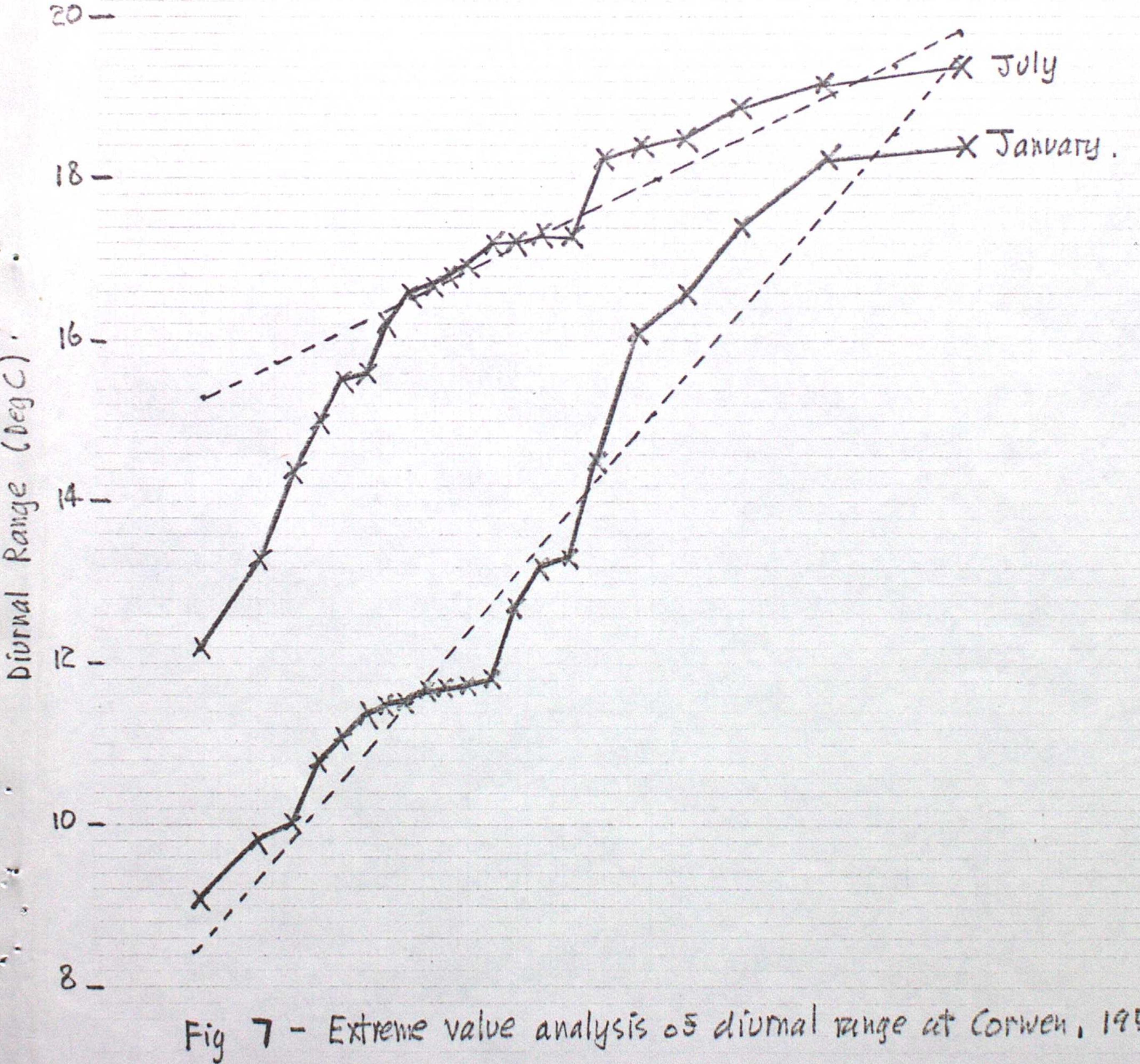


Fig 7 - Extreme value analysis of diurnal range at Corwen, 1959-79.

Dotted lines represent Gumbel distribution obtained by weighting observations

according to [illegible]

FIG 8 – GEOGRAPHICAL VARIATION OF THE SLOPE OF AN EXTREME VALUE ANALYSIS OF DIURNAL RANGE (MEAN OF ALL MONTHS)

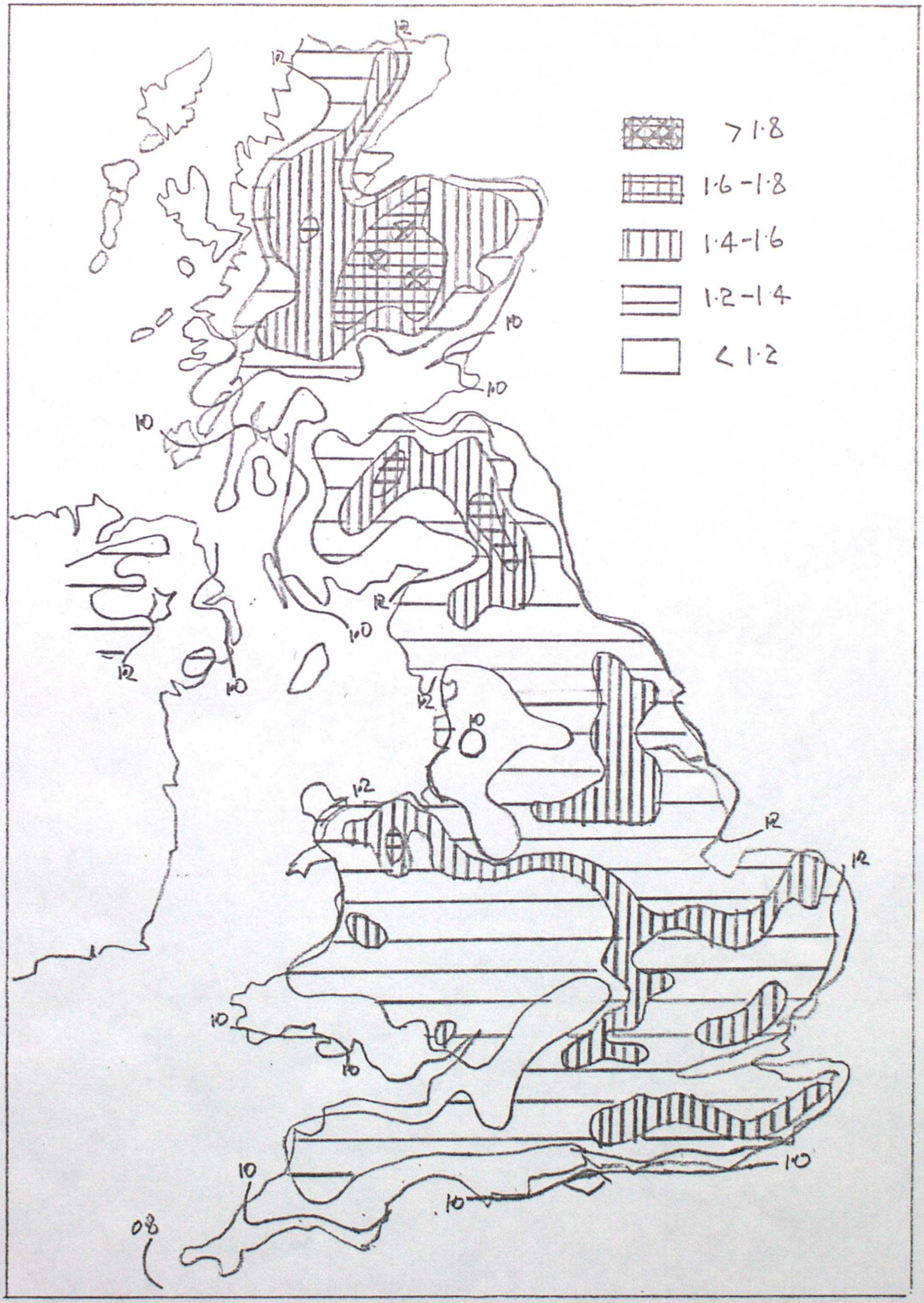


FIG 9 – SEASONAL VARIATION OF DIURNAL RANGE WITH A RETURN PERIOD OF 2 YEARS

(MEAN OF 5 MOST EXTREME STATIONS IN EACH DISTRICT)

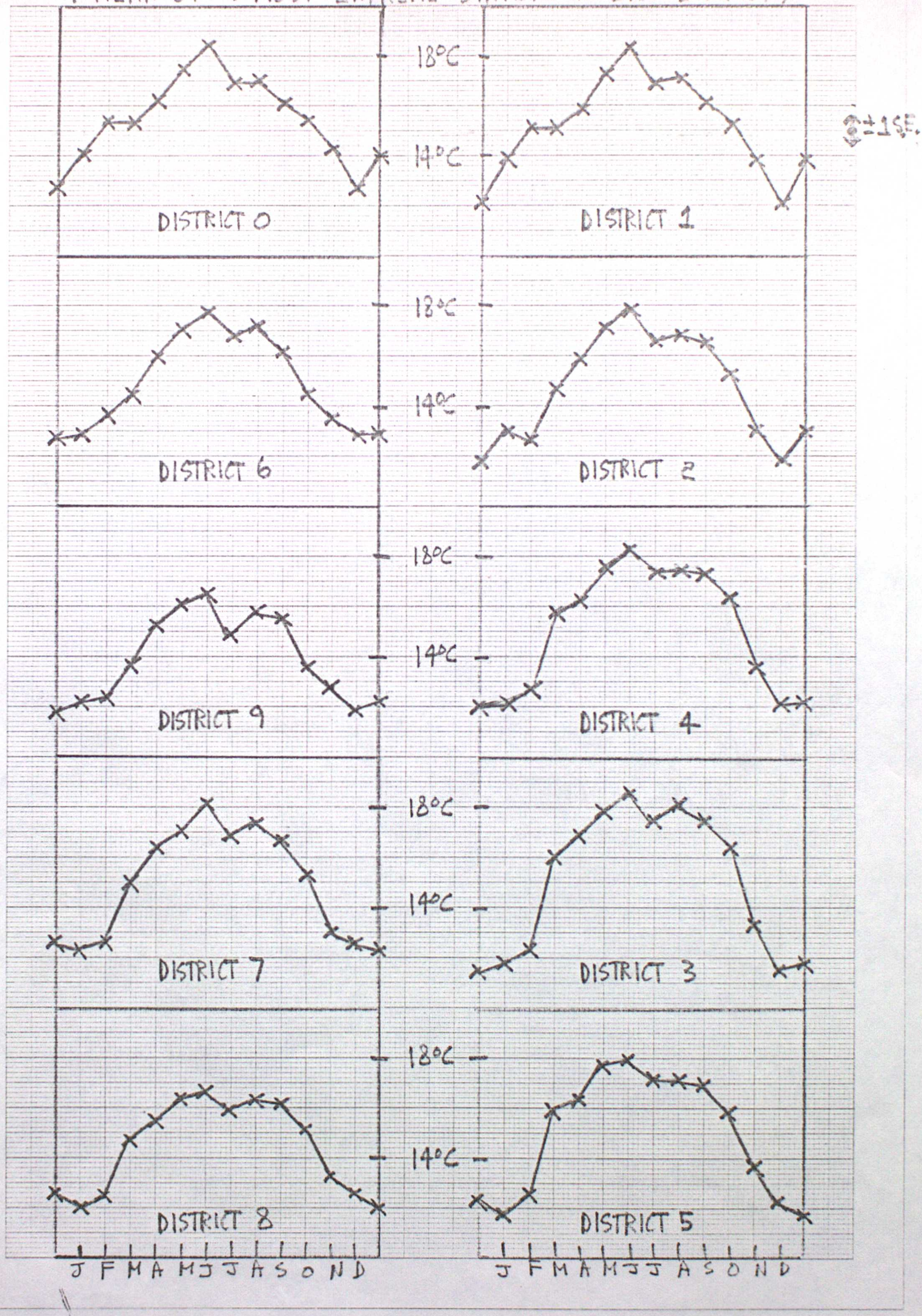


FIG 10 — SEASONAL VARIATION OF THE SLOPE OF AN EXTREME VALUE ANALYSIS OF DIURNAL RANGE

Values represent the mean of the 5 most extreme stations in each district, and have been smoothed

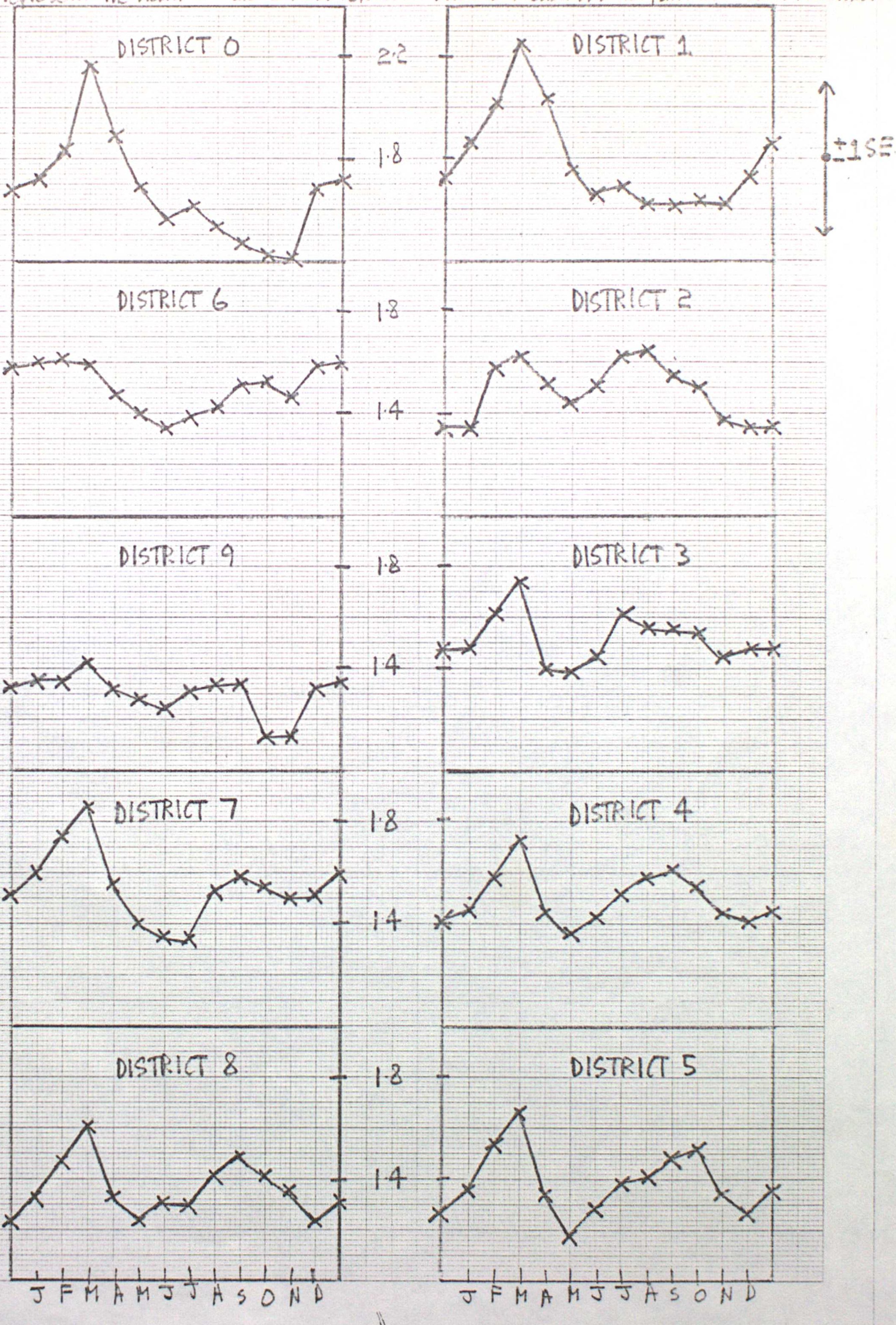


FIG 11 — SEASONAL VARIATION OF DIURNAL RANGE WITH A RETURN PERIOD OF 30 YEARS

Values represent the mean of the 5 most extreme stations in each district, and have been estimated from smoothed values of the 2 year diurnal range and slope of the extreme value analysis.