# THE METEOROLOGICAL MAGAZINE

HER MAJESTY'S STATIONERY OFFICE

June 1984

Met.O.964 No. 1343 Vol. 113

METEOROLOGICAL OFFICE Met. O.964

# THE METEOROLOGICAL MAGAZINE

No. 1343, June 1984, Vol. 113

551.524.31(41–4)

## The diurnal range of temperature over the United Kingdom

By R. C. Tabony

(Meteorological Office, Bracknell)

**Summary**

Geographical and seasonal variations in the diurnal range of temperature over the United Kingdom 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 are important aspects 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 urbanization, distance from the coast, etc.

The effects of topography on frost are best investigated when variations due to other factors, e.g. latitude and altitude, have been minimized. 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 maxima and minima, most practical applications will be concerned with more extreme events — the largest diurnal range in a month, for instance. This is a parameter that 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 of temperature in a month**

Daily values of 24-hour (09–09 GMT) 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 about 570, and their distribution is shown in Fig. 1.

Daily values of diurnal range were calculated from the 24-hour maximum on day $i$ and the 24-hour minimum on 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 procedure 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 that exceeded the mean for the appropriate calendar month by more than 12 °C were rejected. Before 1972, the original daily maximum and minimum temperatures had not been subjected 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 north-west and south-east of the United Kingdom. The average diurnal range would be expected to be greater in the south-easterly 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 the highest diurnal range in a month is likely to be affected by changes of climate across the United Kingdom.

A guide to the answer was obtained by examining the highest daily sunshine totals recorded in a month at about 380 stations in the United Kingdom with fewer 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 percentage of the maximum possible. 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 machinable 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 and that this would be taken as the highest value recorded for that calendar month. The highest daily sunshine totals were then expressed as a percentage of that figure.

For each station the 21 values of highest daily sunshine for each month were ranked and the median values extracted. Geographical variations in these median values, meaned over all months, are

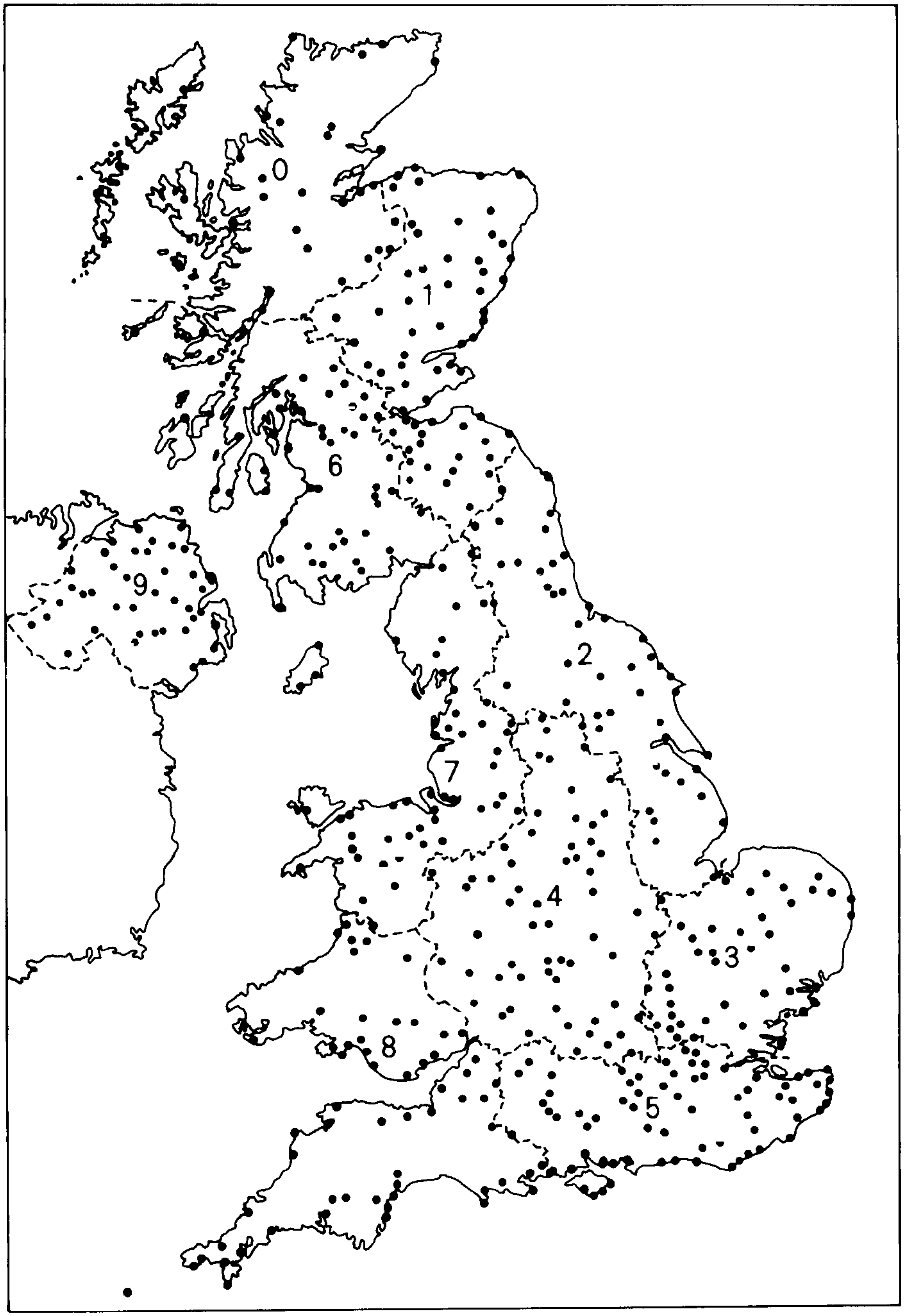


Figure 1. Distribution of stations used to obtain daily values of maximum and minimum temperatures for the period 1959–79. Districts referred to in Figs 9–11 are also shown. (Not all stations can be indicated by separate dots.)

illustrated in Fig. 2. All the maps presented in this paper are generalized 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 ten stations are displayed in Fig. 3. Median values in summer are seen to be higher than in winter, and in the north-west 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 the United Kingdom than in the north-west.

## 4. Geographical variations in diurnal range of temperature

The mean diurnal range, meaned over all months, is displayed in Fig. 4. It is similar to the map first produced by Ashmore (1939) and the main features are:

(i) A general increase from north-west to south-east as the climate becomes less cloudy and windy.

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

(iii) Coastal gradients that are also intense in the south-east, where the sunnier climate enables the potential differences between land and sea to be more fully realized 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 kilometres 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. 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 of temperature

The 21 years of monthly maximum diurnal ranges were plotted on extreme value paper using the

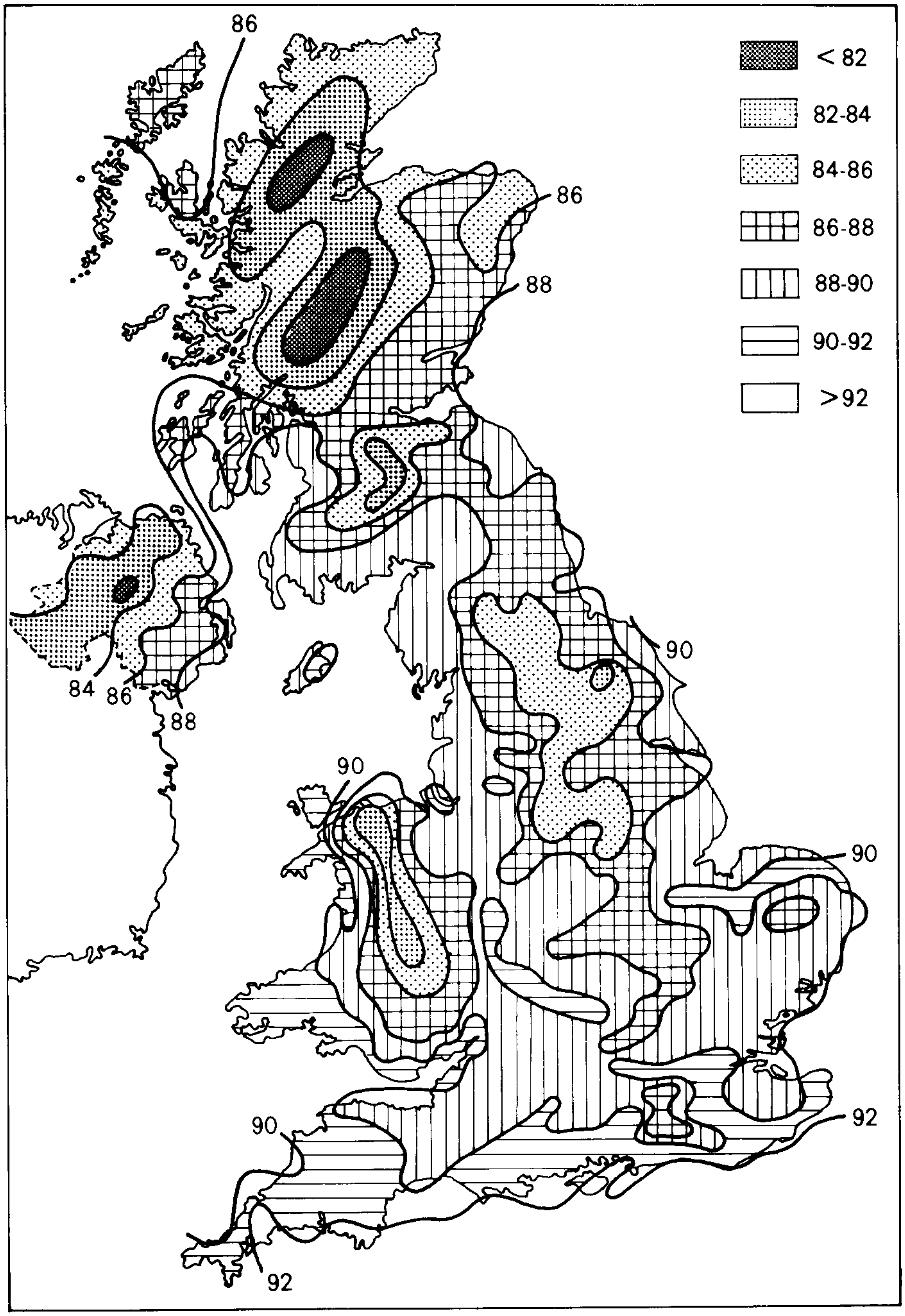


Figure 2. Geographical variation of the median highest daily sunshine in a month. Figures are expressed as a percentage of the sunniest day in each calendar month for the period 1959–79, meaned over all calendar months.

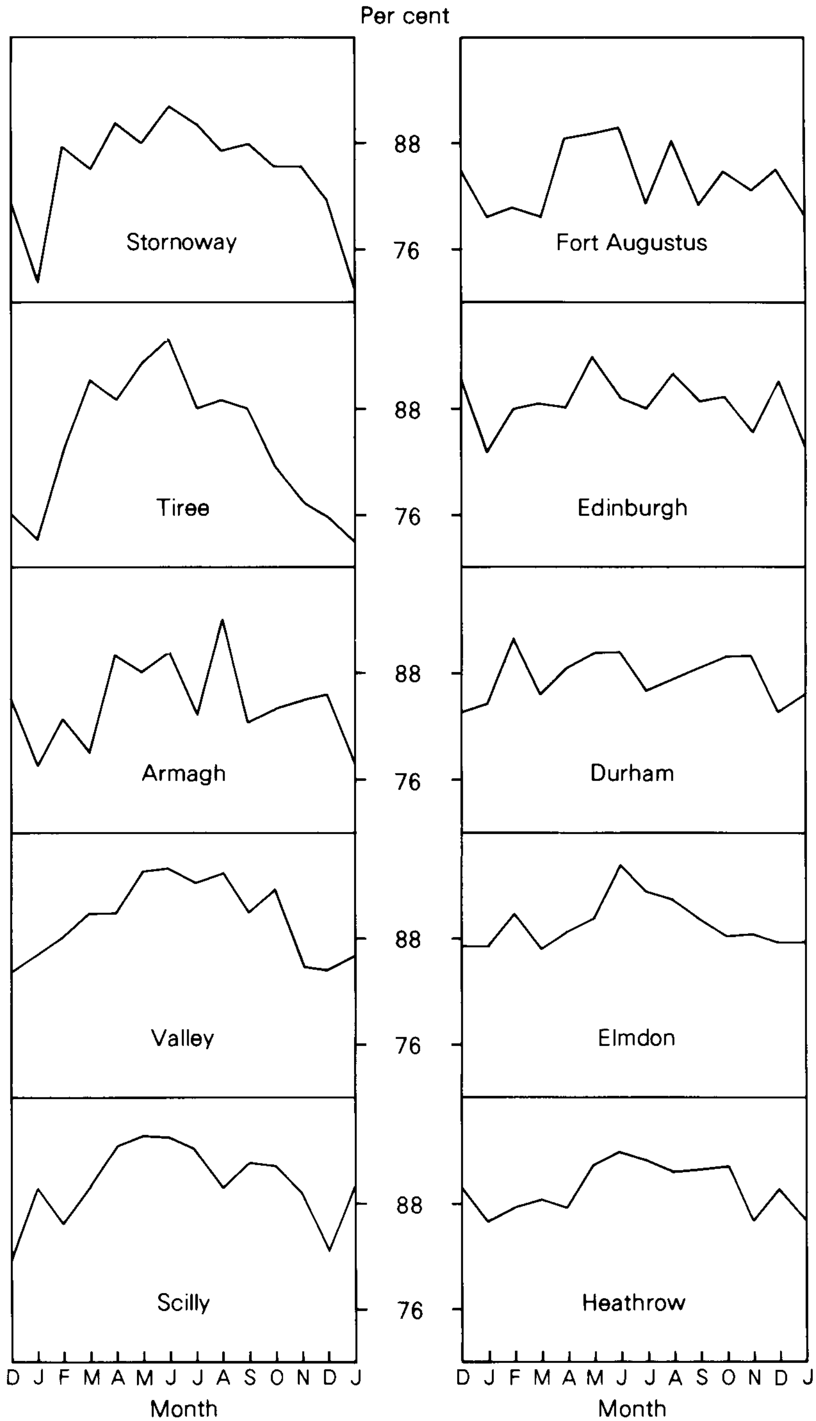


Figure 3. Seasonal variation of the median highest daily sunshine in a month. Figures are expressed as a percentage of the sunniest day in each calendar month for the period 1959–79.

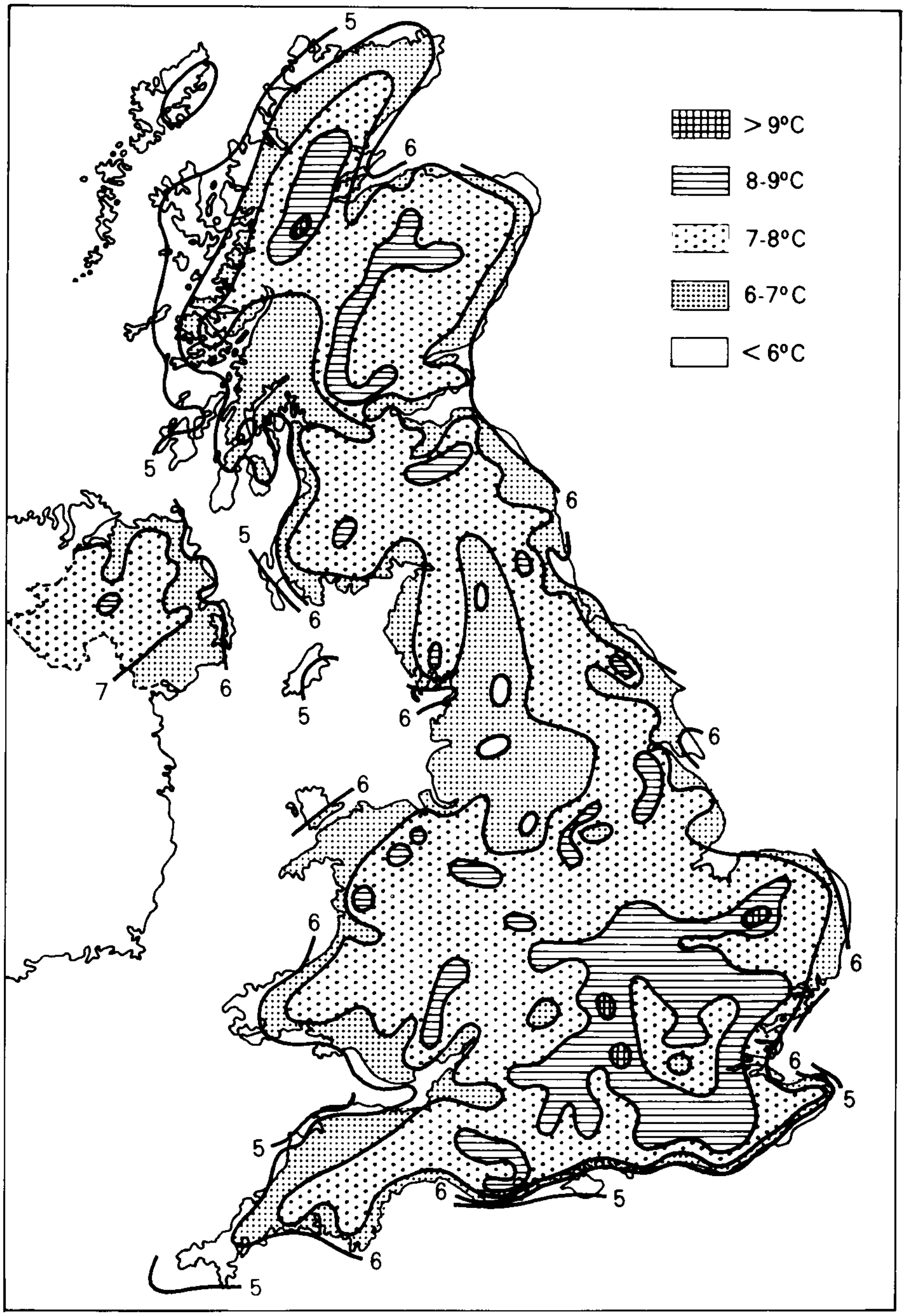


Figure 4. Geographical variation of the mean diurnal range for the period 1959–79 (meaned over all months).

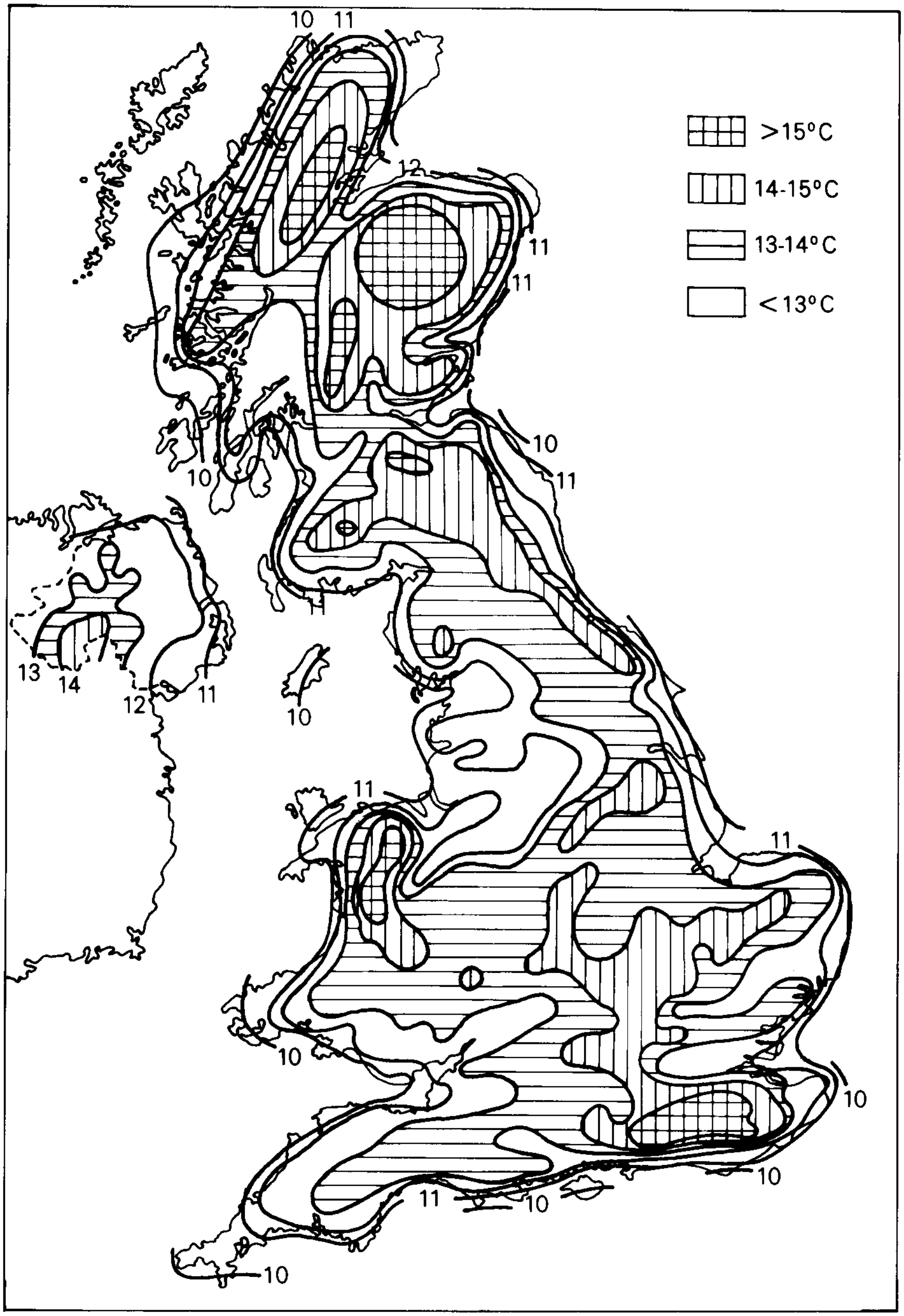


Figure 5. Geographical variation of the mean monthly maximum diurnal range for the period 1959–79 (meaned over all months).

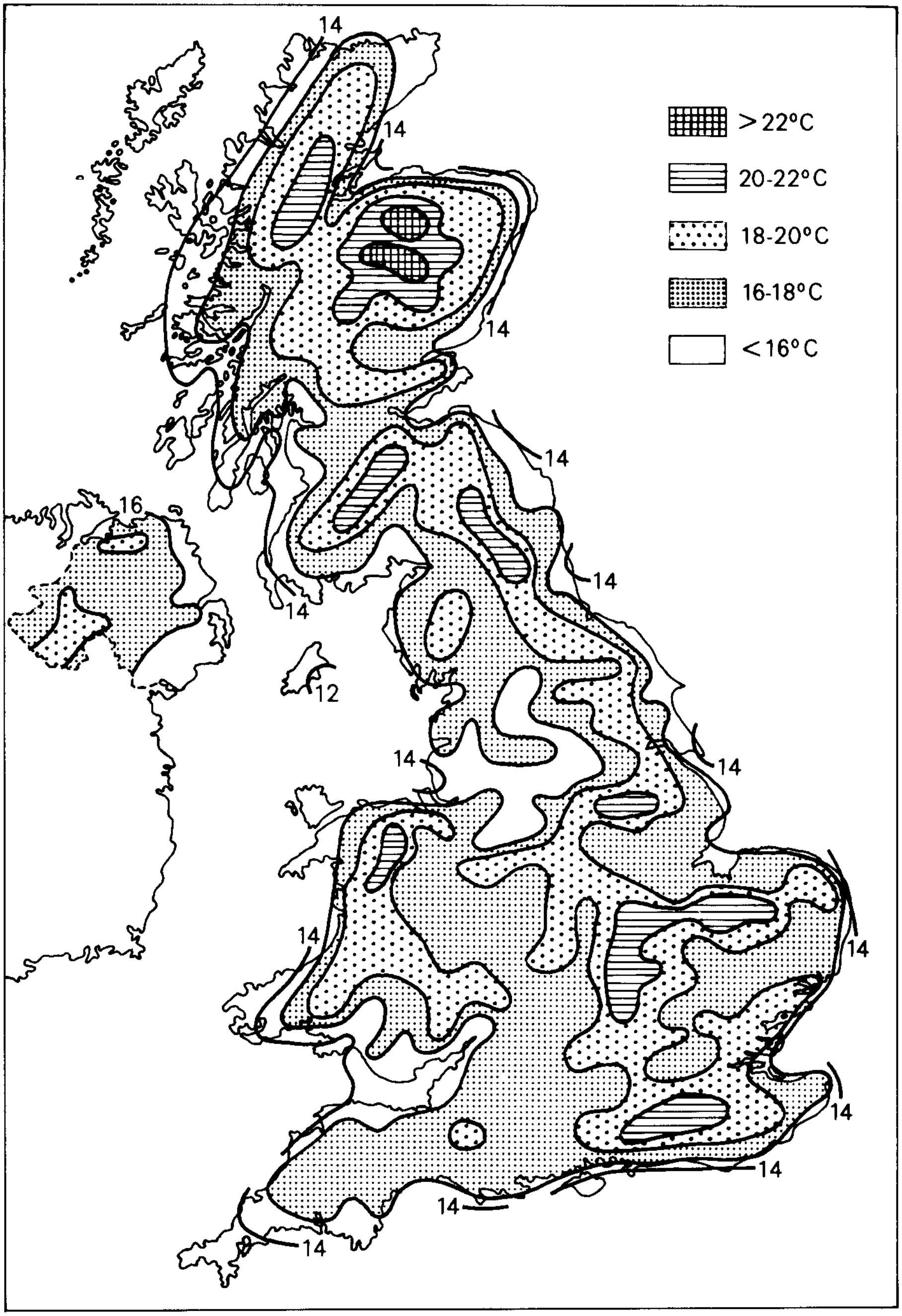


Figure 6. Geographical variation of the largest monthly diurnal range for the period 1959–79 (meaned over all months).

plotting position recommended by Jenkinson (1969), namely

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

where $p$ is the probability ascribed to the $m$th 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.

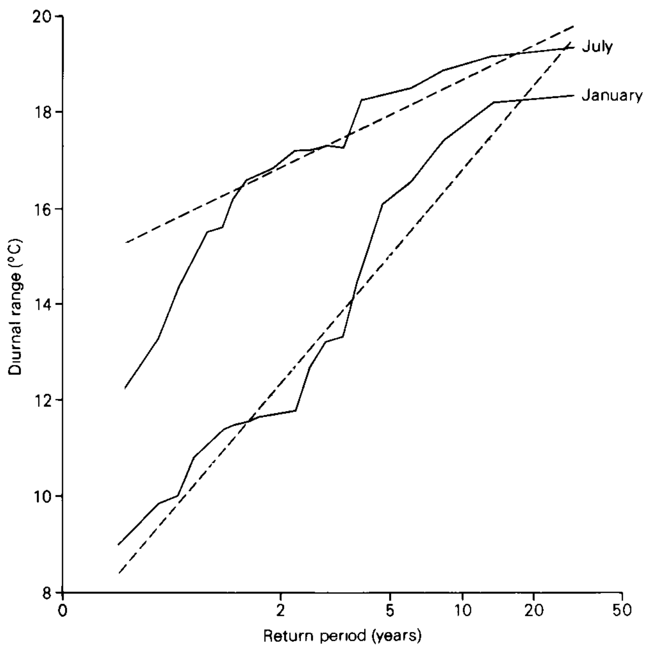


Figure 7. Extreme value analysis of diurnal range at Corwen for the period 1959–79. Dashed lines represent Gumbel distributions obtained by weighting observations according to Jenkinson.

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 of temperature

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

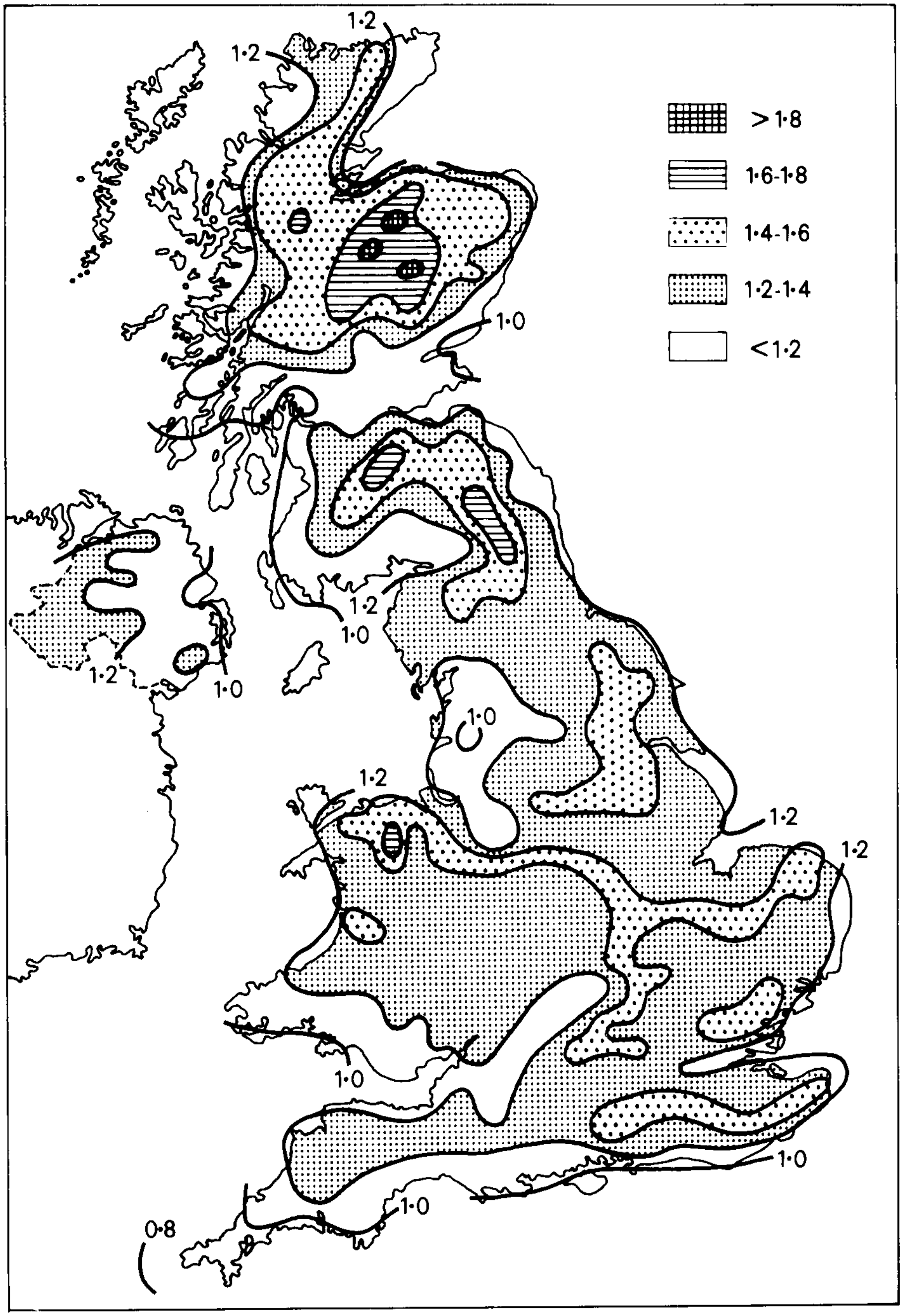


Figure 8. Geographical variation of the slope of an extreme value analysis of diurnal range for the period 1959–79 (meaned over all months).

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 that is characterized 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 two years. For climatological purposes the Meteorological Office has divided the United Kingdom into ten districts, and the diurnal ranges shown in Fig. 9 have been meaned over the five stations with the largest diurnal ranges in each district. In Fig. 9 the districts are positioned according to their approximate geographical location, i.e. 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 (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 the United Kingdom 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. If the standard error of a quantity $q$ is denoted by SE($q$), then for the intercept ($U$), slope ($\alpha$), and ordinal value $X$ of a Gumbel distribution fitted to $N$ observations we have

$$\mathrm{SE}(U) = 1.05\alpha(N)^{-\frac{1}{2}}$$

$$\mathrm{SE}(\alpha) = 0.78\alpha(N)^{-\frac{1}{2}} \quad \ldots \quad (2)$$

$$\mathrm{SE}(X) = (1.11 + 0.52Y + 0.61Y^2)^{\frac{1}{2}}\alpha(N)^{-\frac{1}{2}} \quad \ldots \quad (3)$$

where $Y$ is the value of the reduced variate corresponding to an estimate of $X$ (NERC 1975). The standard error indicated in Fig. 10 has been calculated from equation (2) using $\alpha = 1.8$ and $N = 21$. 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 five 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 held only in manuscript form.

The two-year values of diurnal range were seasonally smoothed 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. Conclusion

The average diurnal range of temperature over the United Kingdom is greatest in the south-east, and decreases to the north-west in response to the cloudier and windier climate. As more extreme events are

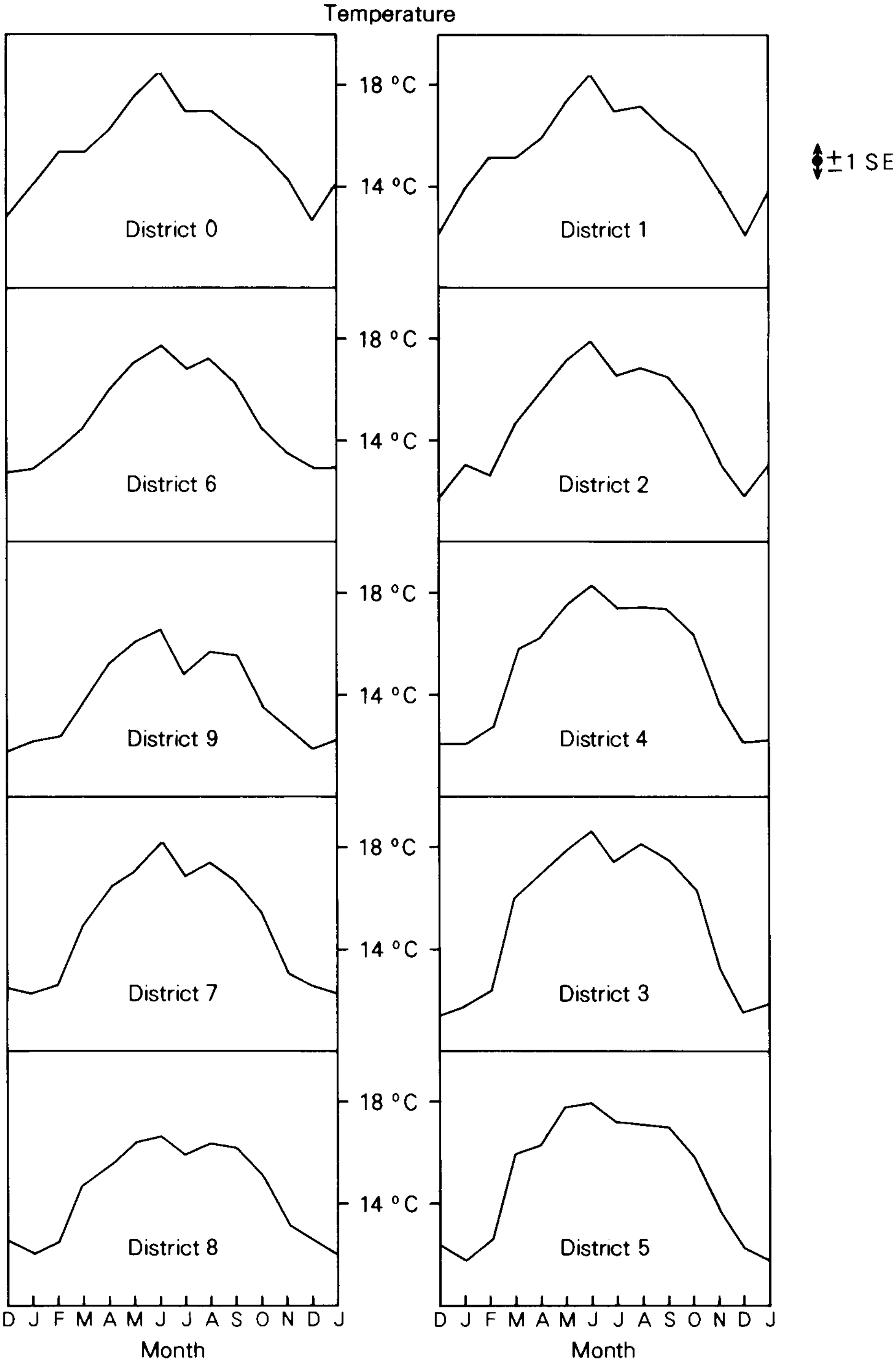


Figure 9. Seasonal variation of diurnal range with a return period of two years (mean of five most extreme stations in each district). ± 1 SE denotes a rough estimate of the relevant standard error, here and in Figs 10 and 11.

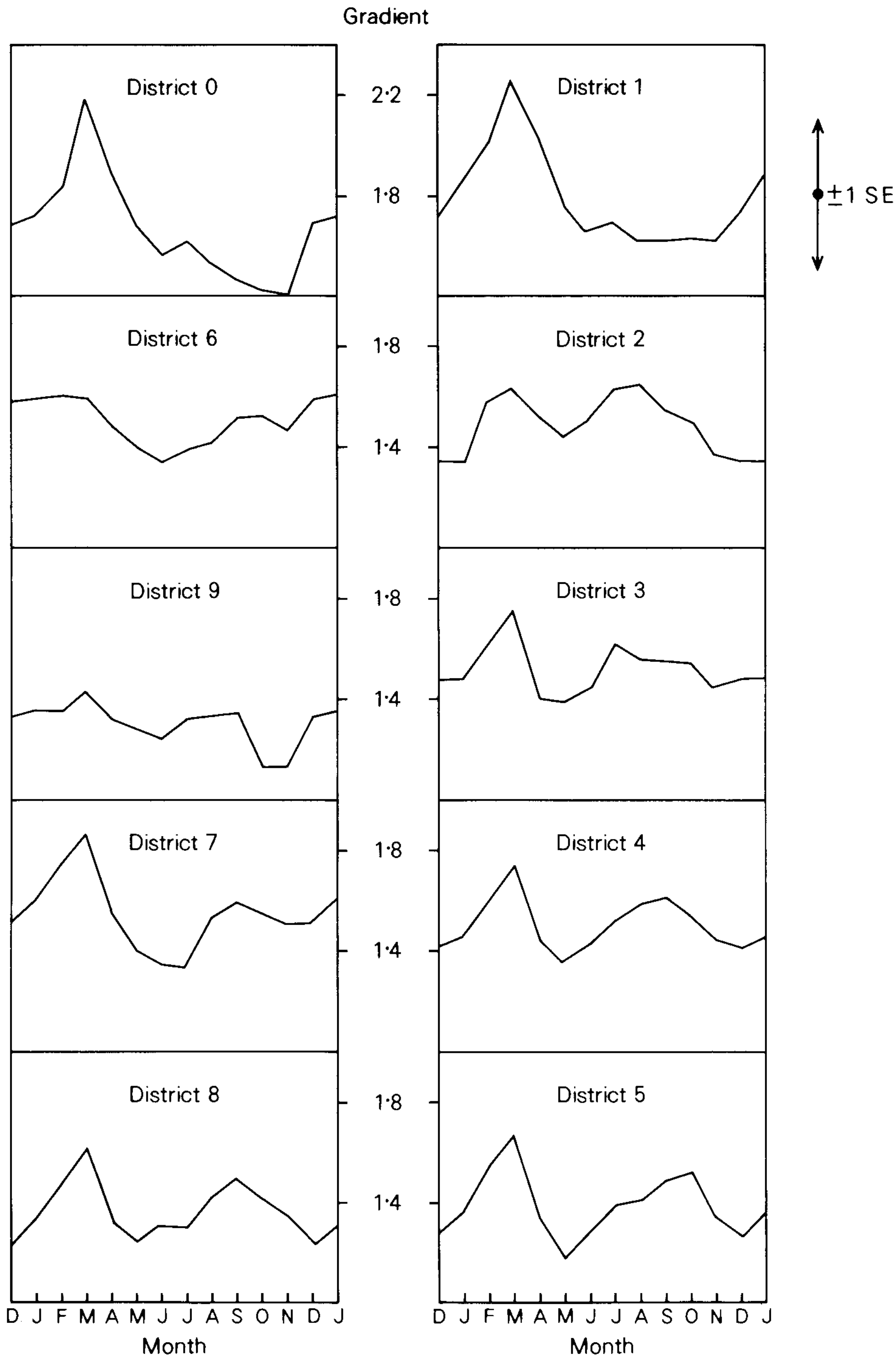


Figure 10. Seasonal variation of the slope of an extreme value analysis of diurnal range. Values represent the mean of the five most extreme stations in each district for the period 1959–79 and have been smoothed.

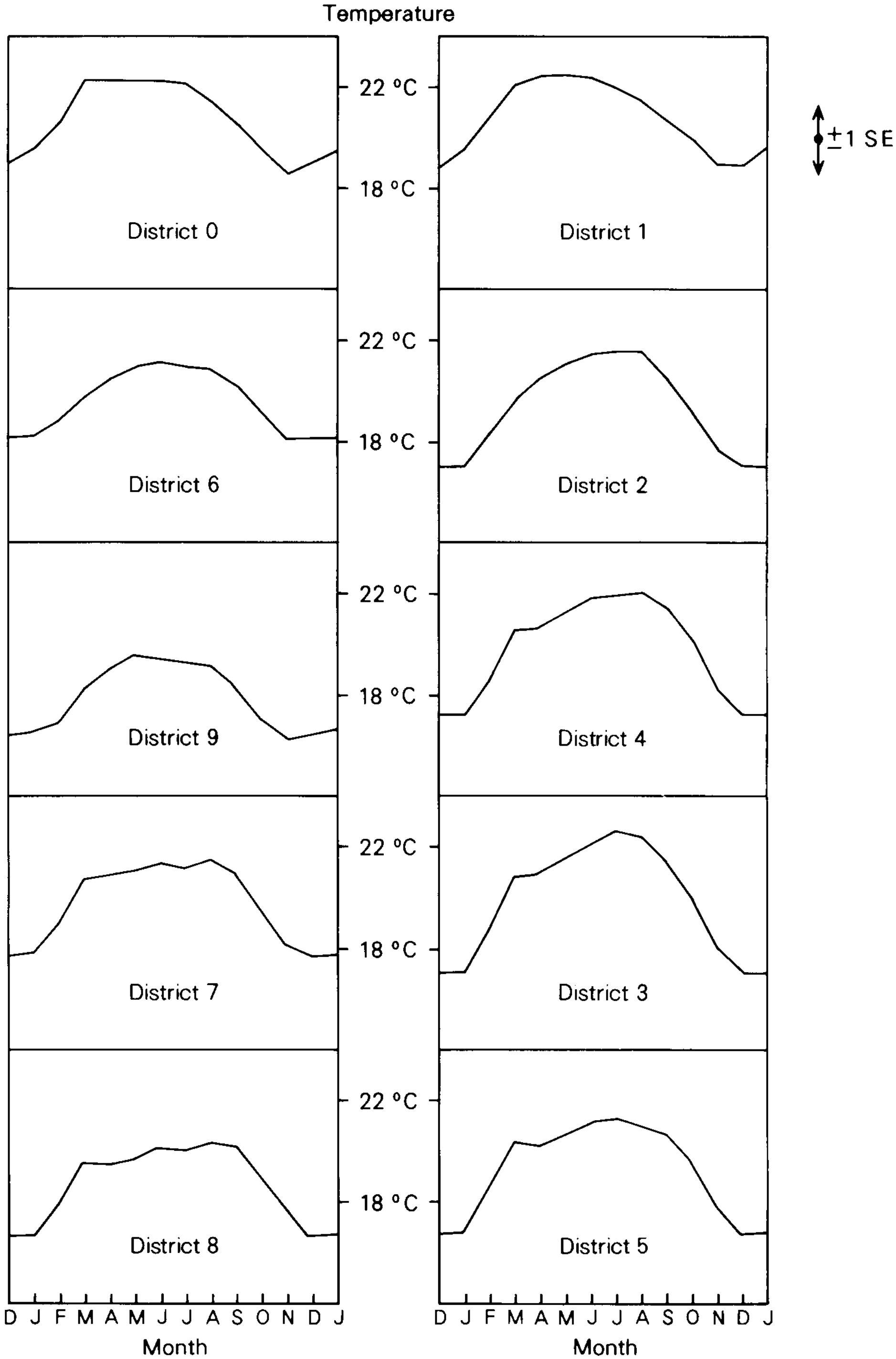


Figure 11. Seasonal variation of diurnal range with a return period of 30 years. Values represent the mean of the five most extreme stations in each district and have been estimated from smoothed values of the two-year diurnal range and slope of the extreme value analysis.

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 R Meteorol Soc*, **65**, 554–558.

Dight, F. H. 1967 The diurnal range of temperature in Scottish glens. *Meteorol Mag*, **96**, 327–334.

Jenkinson, A. F. 1969 Statistics of extremes. *In:* Estimation of maximum floods. WMO Tech Note 98, Geneva, 183–227.

1977 The analysis of meteorological and other geophysical extremes. (Unpublished, copy available in National Meteorological Library, Bracknell).

Lee, A. C. L. 1981 Smoothing and filtering of meteorological data. *Meteorol Mag*, **110**, 115–132.

Natural Environment Research Council 1975 Flood Studies Report Vol. I, London.

Tabony, R. C. 1983 The estimation of missing climatological data. *J Climatol*, **3**, 297–314.


551.553(564.3):551.558.21:533.6.07

# Physical modelling of surface windflow over Cyprus

By B. G. Wales-Smith

(Meteorological Office, London/Heathrow Airport)


**Summary**

The construction and use of a simple wind-tunnel, incorporating an 'inversion surface'* adjustable to 3 levels, and of a crude model of the island of Cyprus are described. Model wind direction data obtained from 4 of the 28 sampling points, with inversions at each of 3 levels, for upstream flow at 10-degree intervals, are compared with surface wind directions observed at 00 GMT throughout 1980 and with corresponding, estimated, upstream 950 mb wind directions, using inversion data sampled by a (daily) 19 GMT radiosonde ascent from one of the four places. The observed and model data are processed in an attempt to validate the latter's predictions, and the model's flow patterns are discussed in the light of experience and of simple physical reasoning.


## Introduction

It is well known by meteorologists and seamen alike that the surface winds around Cyprus form complex patterns in space and time. The former are aware that these patterns result from synoptic-scale pressure systems, from anabatic and katabatic systems, from land- and sea-breeze components and from flow diverted by topography (especially the mountain ranges), and that the vertical lapse-rate of air temperature and the existence and heights of inversions therein are also of great importance.

*'Inversion surface' — horizontal lid modelling an atmospheric temperature inversion.

Many studies have been carried out into the intensity, direction and times of onset and cessation of land- and sea-breezes and of katabatic winds. Forecasters are accustomed to use the results of such studies in combination with first-principle reasoning, experience and an understanding of the three-dimensional structure of the atmosphere and of time changes therein to predict surface winds. This simple experiment and related study, which have various unavoidable limitations, have been carried out in an attempt to gain an objective insight, however coarse, into the purely topographical aspects of low-level airflow over and around the island.

## Wind-tunnel and model

A wind-tunnel (Fig. 1) was constructed from scrap materials, mostly stout packing cardboad, the design being based on a simple diagram of the Meteorological Office wind-tunnel and on a most helpful briefing (Kiff, personal communication).

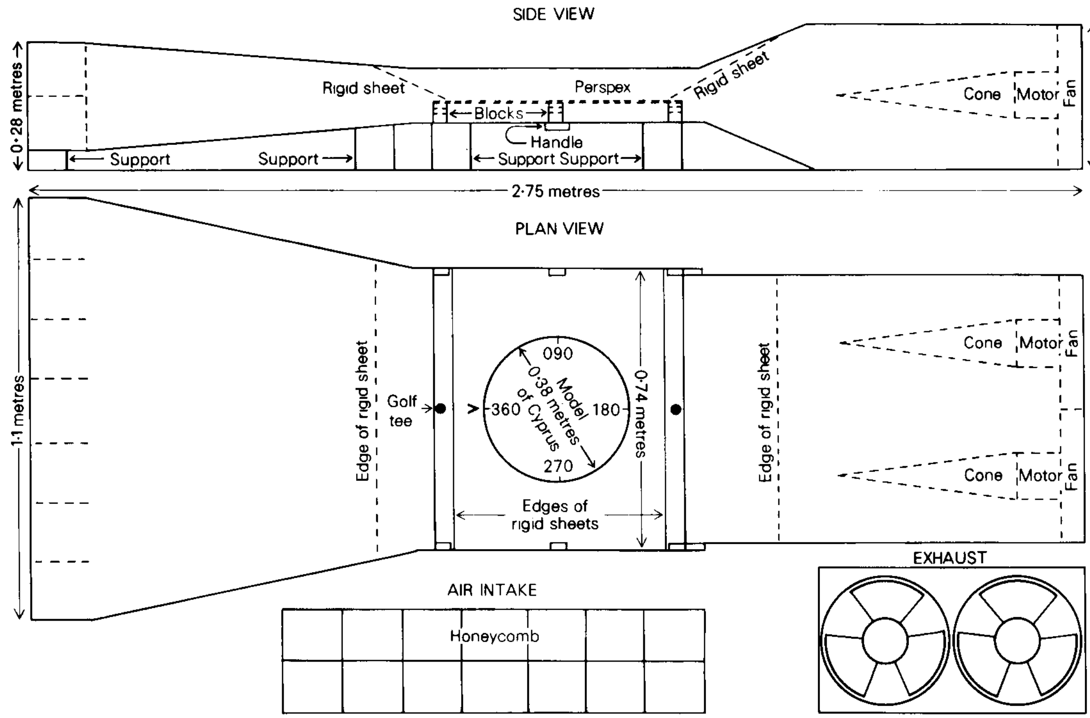


Figure 1. Detail of the wind-tunnel.

The model of the island, on a horizontal scale of 1:750 000, was based on a map the simplified topography of which is employed in various forms by the Cyprus Meteorological Service. The contours were used to shape balsa-wood sheets which were glued together and to a baseboard. The model was then completed using a commercial filler. Because it was decided to use tracing-paper flags 5 mm in height, swinging around pins and resting upon 2 mm diameter metal beads (to reduce friction) it was necessary to enhance the vertical scale very considerably and a factor of ten was selected. This is, in some ways, a fundamental weakness in the experiment and must, to some extent, result in an aerodynamic caricature of flow over and around the island. The turntable upon which the model stands is turned from below by a handle, so that any wind direction can be applied to the model, and fits into a recess in the floor of the working section of the tunnel so that floor level represents sea level. The edge of the turntable is marked at ten-degree intervals. Each of 28 wind direction sampling positions, some at sea, is provided with a 20 mm diameter compass rose (true directions). These positions are shown in Fig. 2. A rigid transparent plastic inversion surface can be set at 2000, 3000 or 4000 m above sea level. These heights correspond roughly to 850, 750 and 650 mb levels. No lower level is practicable because of the height of Mount Olympus (1936 m). With the inversion at 4000 m the cross-section of the working volume is considerably less than one quarter of the cross-section of the air intake. The lengths of the intake and exhaust sections are one-and-a-half times that of the working section and, if the tip of the panhandle of Cyprus is ignored, the model is only one third of the width of the working section. Two three-speed domestic fans (the most powerful available) set at maximum speed produce a four-knot flow across the model (measured by hand anemometer). Three pairs of golf tees of appropriate lengths, are used (one pair at a time) on the centre line to prevent the plastic inversion from sagging under its own weight. Space available for the construction and use of the wind-tunnel limited its size which, in turn, limited the size of the model.

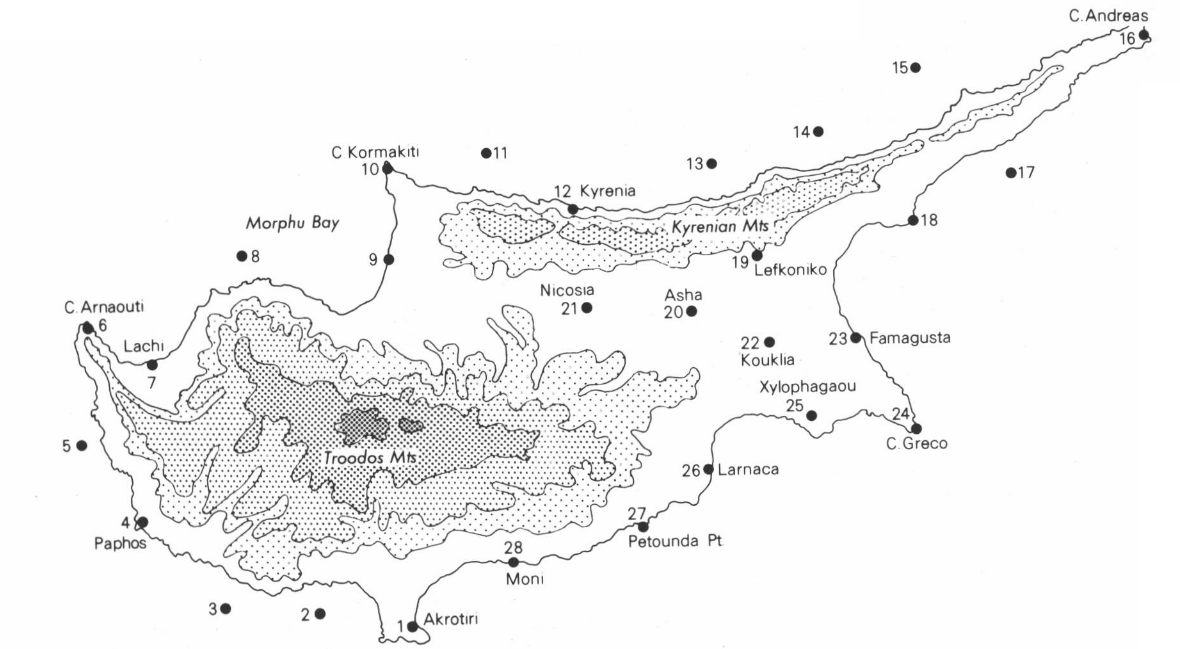


Figure 2. Plan of the model showing basic land contours and the 28 sampling positions. (The map reproduced here is not the one employed by the Cyprus Meteorological Service and was not used in the construction of the model.)

## Wind direction data from the model

Three 'runs' were carried out, twice each, for inversions at 2000, 3000 and 4000 m. The sampling-position flag directions were tabulated against the direction of the turntable. Directions at position 12 (Kyrenia) were interpolated from positions 11 and 13 because the model island prevented the flag from turning through 360 degrees. The data for the 2000 m inversion were plotted on maps of approximate scale 1:2250000 and quality control was imposed only to remove 'noise' obviously due to very occasional flag sticking and only those values which could be rejected with confidence were amended. The final values were plotted on maps of the above scale and simple streamlines drawn. To save space only enough of those of the 2000 m map series needed to illustrate this text are reproduced (Figs 3(a)–(i)).

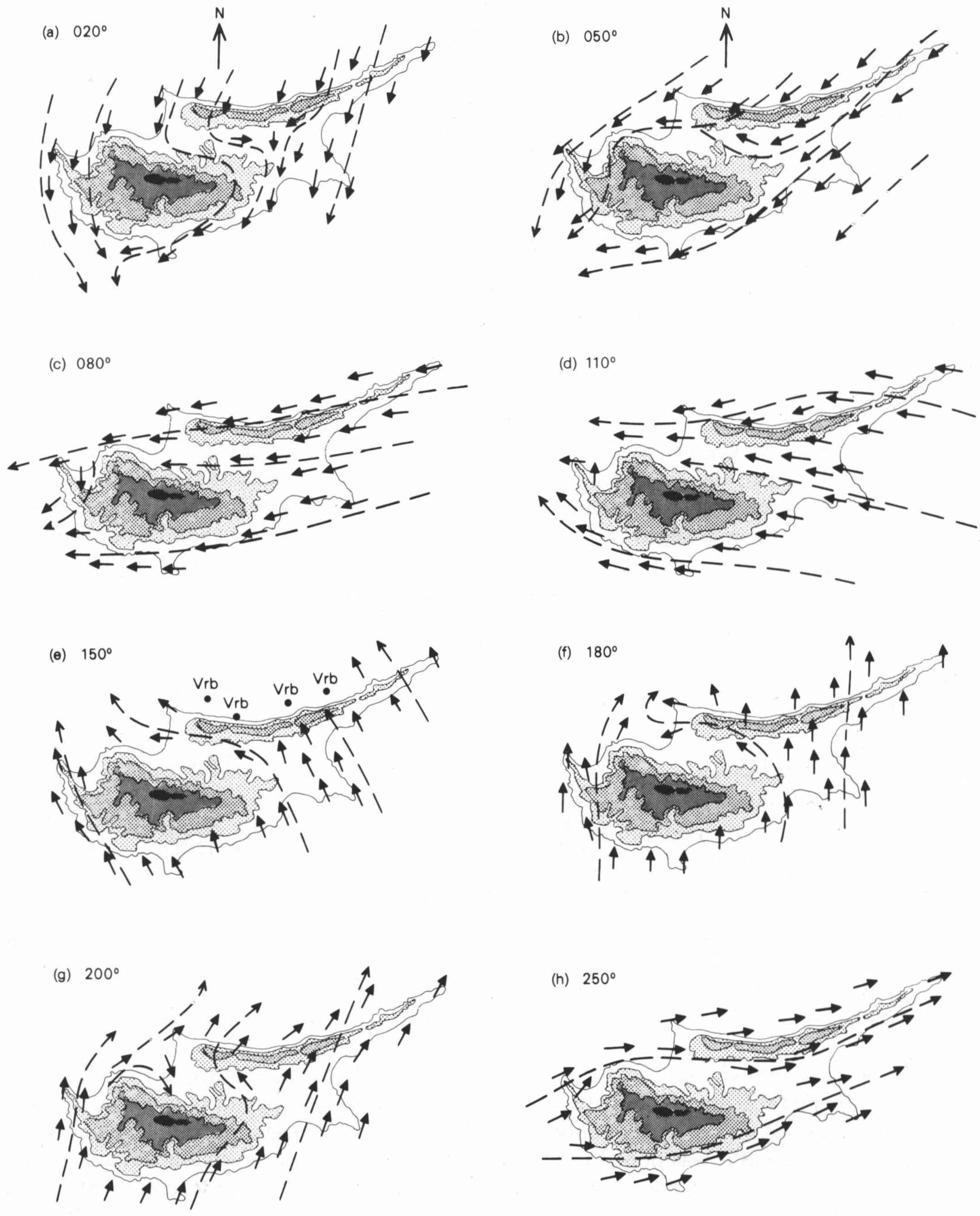


Figure 3 (a)–(i). Streamline patterns drawn from spot wind directions recorded by the model's flags, with inversion at 2000 m and upstream flow direction as shown. Vrb—variable.

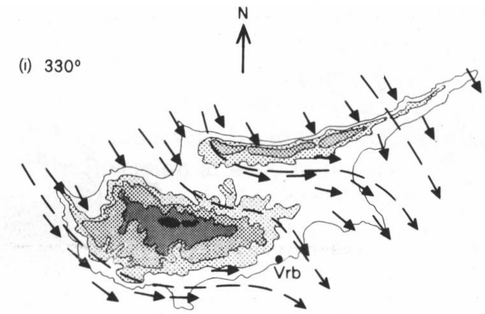


Figure 3 continued.

**Real wind and inversion data**

The sampling time for real data was chosen as 00 GMT because it is the closest main synoptic chart time to radiosonde time (19 GMT) at which sea-breezes would never be expected, and because it is an upper-air chart time in case upper-wind data were found to be required. The 950 mb wind direction over and upstream of the island was estimated from the mean-sea-level isobars. This simplification, however necessary, introduces the implied assumption that the gradient wind over and upstream of Cyprus always remains virtually unchanged for long enough to allow topographical controls on windflow to become effective all over the island. It ignores the existence and transit across the island of fast-moving, short wavelength synoptic systems. Surface wind direction data for 00 GMT were available from Nicosia, Akrotiri, Larnaca and Paphos only.

Tephigrams of the daily radiosonde ascents, then made from Akrotiri, were examined and details of inversions were extracted. Here reference is made only to inversions in broad classes of height.

Wind direction and inversion data were tabulated to the format:

| $I_t$ | Main flow | Nicosia | Akrotiri | Paphos | Larnaca |
|---|---|---|---|---|---|
| | $dd_{950}$ | dd | dd | dd | dd |
| | | (dd) | (dd) | (dd) | (dd) |
| | | Diff | Diff | Diff | Diff |

where $I_t$ — inversion type,
$dd_{950}$ — estimated 950 mb wind direction over and upstream of Cyprus,
dd — observed surface wind direction at 00 GMT,
(dd) — model surface wind direction for $dd_{950}$ and $I_t$,
Diff — difference between dd and (dd) (0 to 18, i.e. tens of degrees).

There were 299 cases of inversions below 750 mb (perhaps with higher inversions), 17 cases of inversions only between 750 and 650 mb and 50 cases of inversion only above 650 mb or of no inversion. The last mentioned were classed with inversions above 650 mb because the wind-tunnel flags would not operate with the lid removed and it was hoped to obtain model values for 'no inversion' cases.

The island has an irregular shape, but if the panhandle is ignored its west-to-east extent is some 80 nautical miles. Hence a ten-knot airstream would have to persist and remain virtually steady in direction for up to eight hours to cross the main bulk of the island for topographical controls to take effect everywhere. Table I is a sequential plot of day-to-day changes in estimated 950 mb wind direction at 00 GMT in 1980 (in tens of degrees). The convention has been adopted that the wind never changed

**Table I.** *Changes of estimated 950 mb wind direction, in tens of degrees, immediately upwind of Cyprus at 00 GMT in 1980 for the previous 24 hours*

| | Day | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| Jan. | 6 | 10 | 5 | 5 | 9 | 16 | 2 | 3 | 6 | 2 | 12 | 2 | 0 | 1 | 2 | 7 | 7 | 2 | 5 | 7 | 1 | | | 9 | 4 | 2 | 0 | 14 | 2 | 7 | |
| Feb. | 0 | 2 | 5 | | | | | | 1 | 3 | 4 | | | 4 | 7 | 2 | 5 | 4 | 9 | 3 | | | 3 | 1 | | | | 16 | 0 | — | — |
| Mar. | 2 | 6 | 2 | 11 | 1 | | | 1 | 18 | 5 | 4 | 13 | 1 | 17 | 12 | 5 | | | 3 | | | | 4 | 1 | 10 | 12 | 0 | 16 | 1 | | |
| Apr. | 2 | 0 | 15 | 4 | 2 | 16 | 3 | 18 | 17 | 18 | 1 | 0 | 3 | 1 | 4 | 1 | 8 | 9 | 14 | 7 | 14 | 2 | | | 3 | 1 | 13 | 8 | 9 | 6 | — |
| May | | | 12 | 4 | | | 8 | 11 | 1 | 1 | | | 18 | 5 | 6 | 4 | 2 | 15 | 8 | 5 | 16 | 1 | 1 | 15 | | | 4 | | | | 6 |
| June | 8 | 6 | 4 | 6 | 3 | 3 | 2 | 0 | 5 | 3 | 5 | 2 | 2 | | | | | | 4 | 1 | 3 | 2 | 0 | 3 | | | | | | | — |
| July | 0 | 4 | | | | 0 | 7 | 3 | 8 | 2 | | | 1 | 3 | | | | | | | | 8 | 4 | 1 | 3 | 1 | | | 3 | | |
| Aug. | | | | 1 | 2 | 2 | 5 | 4 | 9 | 10 | | | 3 | 2 | 11 | 6 | 7 | 4 | 0 | 8 | 9 | 4 | 6 | 12 | 8 | 8 | | | | 3 | 0 |
| Sept. | 1 | 2 | 2 | 0 | | | | | 1 | 2 | 3 | | | 1 | 3 | 2 | 2 | 6 | 4 | 0 | 4 | 0 | | | 7 | 7 | 0 | 3 | | | |
| Oct. | 2 | 2 | 1 | 0 | 1 | 9 | 0 | 5 | 6 | 2 | 1 | 1 | | | | | | 3 | 1 | 3 | 0 | 5 | 17 | | | | 10 | 8 | 6 | 6 | 10 |
| Nov. | 8 | | | 7 | 3 | 8 | | | 12 | | | 2 | 17 | 1 | 5 | 1 | 0 | 6 | 1 | | | 4 | 11 | 1 | 3 | 3 | 5 | 1 | | | — |
| Dec. | | 4 | 6 | 2 | 10 | 1 | 7 | | | 1 | 6 | | | | | | 4 | 7 | 5 | 4 | 4 | 3 | 1 | 12 | 1 | | | 2 | 4 | 10 | 1 |

through more than 180°. Breaks in the sequence are due to calms. The table gives an impression of the variability of 950 mb wind direction in 1980. It shows 68 occasions when the estimated wind direction did not change by more than 20° in 24 hours for from 24 to 120 hours and there must have been many other occasions when the wind speed was sufficiently strong and the 'pre-00 GMT' direction sufficiently constant for topographical controls to operate by 00 GMT. Hence it seems reasonable to assume that the data are adequate for an attempt at simple verification of the model in terms of there being enough occasions when a steady flow lasted long enough. It is also necessary to be sure that all 950 mb wind directions are represented in the real data. Fig. 4 shows numbers of cases estimated from each ten-degree point with calms at the centre. It could reasonably be argued that some of the 22 cases of 360° probably belonged to 350° and 010°. Accordingly, numbers of cases in 36 overlapping 50° sectors were averaged to give the smoothed totals. It can be seen that the most frequently occurring directions were well sampled but that the infrequent southerlies were less well sampled; there are, however, probably enough for the present purpose.

The processes of data extraction and processing are extremely time-consuming and only one year's data are presented. This is probably not a serious drawback because local wind components (other than topographical ones) occur at 00 GMT and at the other three major synoptic hours and hence the chance of direct verification of purely topographical effects is unlikely to increase significantly with quantity of data.

## Data analysis and discussion

Twelve scatter diagrams were plotted as listed in Table II. Numbers 1 to 4 are straightforward comparisons of model-predicted versus observed wind directions at the 4 locations for all cases (inversion at any level or none at all). Numbers 5 to 7, for Akrotiri only (the location from which the radiosonde ascents were made), make the same comparison but for three separate classes of inversion level. Numbers 8 to 11 compare the estimated 950 mb wind direction for inversions at 750 mb and below with the observed (surface) wind directions at the four locations. Number 12 makes the same comparison, for Akrotiri only, for cases when the inversion was at some level higher than 750 mb and when there was no inversion at all. The data tabulated are, firstly, numbers and percentages of total cases where the directions agreed to within 30°, secondly, any tendency for points to cluster in defined parts of the diagrams and, thirdly, any tendency for observed surface wind directions to cluster when the model-predicted or estimated 950 mb wind was calm. Clustering on the scatter diagrams was assessed by inspection. The total ranges of direction are given in the clockwise sense.

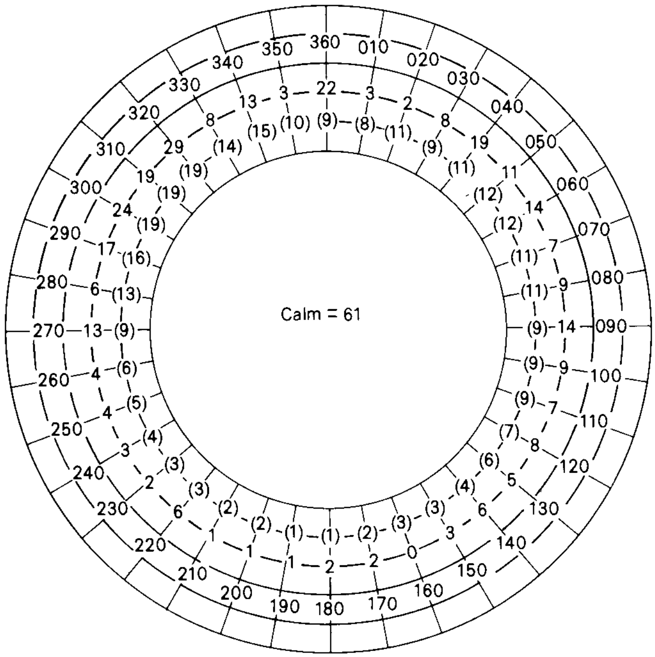


Figure 4. Numbers of cases of estimated 950 mb wind direction immediately upwind of Cyprus at 00 GMT in 1980 from every 10° direction. Values in brackets are meaned over overlapping 50° sectors. (Monthly distributions of estimated daily 950 mb flow reflected the dominance of the seasonal trough from June to September when all directions fell between west and north-east (through north)).

Starting with comparisons 8 to 11 only 36% or less of observed surface winds were within 30° of estimated 950 mb winds and there was marked clustering. This shows that local effects, including topographical controls, are important at all four locations and that the results of such effects are systematic. Taking comparisons 1 to 4 and 8 to 11 in pairs (i.e. one place at a time) there are marked similarities between the clustering characteristics when the model predicted a wind direction.

The contents of the first four blocks in the last column of Table II should explain much of the difference between observed winds and model winds. The observed winds in the ranges given in these blocks occurred when no synoptic-scale pressure gradient could be identified and should, therefore, be due to temporary thermal gradients set up over the island and surrounding sea. The first step was to examine the distributions of reported directions on these 61 occasions, separating from the others those which appear to have been katabatic winds; this is done in Table III.

**Table II.** *Summary of 12 scatter diagrams*

| Station | Comparison | $I_t$ | Cases | No. of cases within 30° | Percentage | Clustering (degrees true) (dd) vs dd | (dd) calm vs dd |
|---|---|---|---|---|---|---|---|
| 1. Nicosia | (dd) vs dd | Any level or none | 359 | 116 | 32 | 090–120/200–260<br>270–310/080–220 | calm/180–260<br>calm/100–170 |
| 2. Akrotiri | (dd) vs dd | Any level or none | 366 | 149 | 41 | 060–120/240–010<br>220–270/320–350 | calm/300–050<br>calm/060–100<br>calm/230–290 |
| 3. Paphos | (dd) vs dd | Any level or none | 366 | 139 | 38 | 110–130/010–060<br>300–320/010–070 | calm/350–100<br>calm/270–340 |
| 4. Larnaca | (dd) vs dd | Any level or none | 366 | 90 | 25 | 040–070/310–360<br>080–140/310–030<br>310–360/220–260 | calm/260–320<br>calm/330–010 |
| 5. Akrotiri | (dd) vs dd | 750 mb and below | 299 | 113 | 38 | As 2 | As 2 |
| 6. Akrotiri | (dd) vs dd | 750–850 mb | 22 | 10 | 45 | Too few cases | – |
| 7. Akrotiri | (dd) vs dd | Higher than 750 mb or none | 67 | 36 | 54 | Too few cases | – |
| | | | | | | $dd_{950}$ vs dd | $dd_{950}$ calm vs dd |
| 8. Nicosia | $dd_{950}$ vs dd | 750 mb and below | 294 | 42 | 14 | 310–140/240–260<br>290–320/220–230<br>040–140/220–230 | As 1 |
| 9. Akrotiri | $dd_{950}$ vs dd | 750 mb and below | 299 | 86 | 29 | 310–360/240–260<br>360/270–300<br>030–110/320–360<br>030–050/240–290 | As 2 |
| 10. Paphos | $dd_{950}$ vs dd | 750 mb and below | 299 | 108 | 36 | 280–360/010–040<br>010–070/330–360 | As 3 |
| 11. Larnaca | $dd_{950}$ vs dd | 750 mb and below | 299 | 76 | 25 | 300–360/230–250<br>030–140/310–360 | As 4 |
| 12. Akrotiri | $dd_{950}$ vs dd | Higher than 750 mb or none | 67 | 25 | 37 | Too few cases | – |

dd — observed surface wind direction at 00 GMT, (dd) — model surface wind direction for $dd_{950}$ and $I_t$, $dd_{950}$ — estimated 950 mb wind direction over and upstream of Cyprus.

**Table III.** *Distributions of observed surface wind directions (degrees true) at four locations in Cyprus at 00 GMT in 1980 on 61 occasions of indeterminate surface pressure gradient*

| Station | Katabatic winds Direction (degrees true) | No. of cases | No. of calms | Other winds Direction (degrees true) | No. of cases | Percentage of total |
|---|---|---|---|---|---|---|
| Nicosia | 180–260 | 40 | 1 | 060 | 1 | |
| | | | | 100–170 | 8 | |
| | | | | 270–300 | 10 | |
| | | | | 360 | 1 | 33 |
| Akrotiri | 300–050 | 27 | 6 | 060–100 | 13 | |
| | | | | 180 | 1 | |
| | | | | 230–290 | 14 | 45 |
| Paphos | 350–100 | 28 | 15 | 130–140 | 3 | |
| | | | | 220 | 1 | |
| | | | | 240–250 | 2 | |
| | | | | 270–340 | 12 | 29 |
| Larnaca | 260–320 | 24 | 17 | 030 | 1 | |
| | | | | 200 | 1 | |
| | | | | 220 | 2 | |
| | | | | 250 | 2 | |
| | | | | 330–010 | 14 | 33 |

As the wind-tunnel and model were unable to measure wind speeds at the sensing locations there was no point in extracting speeds at the four test stations. In an attempt to obtain rough estimates of the direction of the assumed 'thermal wind' components relating model winds to observed winds it was assumed that all model winds blew at five knots and that all observed winds blew at ten knots. A simple vector device was used with the data from the first four blocks in the next to last column in Table II. The directions limiting ranges of 'thermal wind' obtained by this method are given in Table IV which also contains the katabatic wind ranges of Table III.

**Table IV.** *Limits of ranges of approximated directions (degrees true) of local, thermal components assumed present in winds measured at four locations in Cyprus at 00 GMT in 1980. (Katabatic wind direction ranges are also given.)*

| Station | Directions of estimated thermal winds | | | Katabatic wind range |
|---|---|---|---|---|
| Nicosia | 080–190 | 220–270 | | 180–260 |
| Akrotiri | 240–350 | 340–010 | | 300–050 |
| Paphos | 350–030 | 040–090 | | 350–100 |
| Larnaca | 280–330 | 300–360 | 200–240 | 260–320 |

Assuming that the reasoning so far is broadly valid and accepting that, whilst katabatic winds have preferred directions, the direction of flow on an individual night often owes much to other causes, the components still to be explained are:

Nicosia 080–170°, 270°,
Akrotiri 240–290°,
Paphos nil,
Larnaca 200–240°, 330–360°.

Wales-Smith (1984) has demonstrated that the average mean-sea-level pressure at Nicosia is higher than

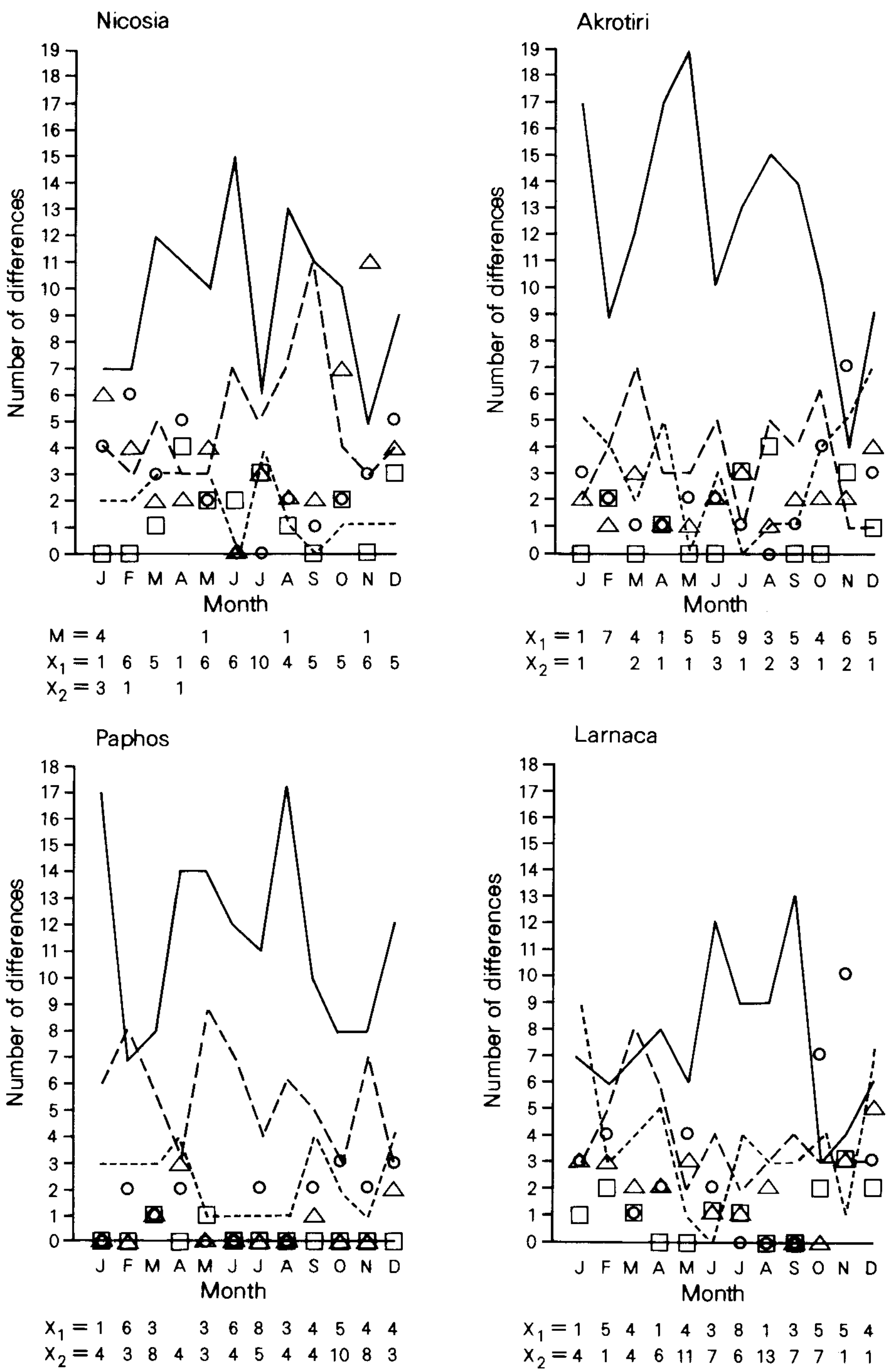


Figure 5. Monthly comparisons between model-predicted and observed surface wind directions at four stations in Cyprus. (——— cases of 0–30° difference, — — — 40–60°, - - - - - 70–90°, ○ 100–120°, △ 130–150°, □ 160–180°, M = no observation, $X_1$ = wind observed when model predicted calm, $X_2$ = calm observed when model predicted wind.

at three well-separated coastal places at 00 GMT throughout the year. The 14 cases of flow 330–010° at Larnaca (from Table III) occurred throughout the year, and thus may be explainable as land-breeze phenomena.

Unexplained occurrences of other 'thermal winds' in Table III nearly all occurred in the summer months and may have been due to exceptional differences of surface temperature persisting into the night; they are summarized as follows:

Nicosia: Six out of eight cases of 100–170° occurred in June and July.
Seven out of ten cases of 270–300° occurred in May, June and July.
Akrotiri: Eight out of fourteen cases of 230–290° occurred in June to September.
Larnaca: Four out of five cases of 200–250° occurred in July and September.

Although there were no cases to be explained at Paphos there remain 15 cases in Table III from directions between 220° and 240°; 8 of these occurred in the months from May to September. Presumably those in the cooler months occurred due to weak synoptic-scale gradients not revealed by the sparse data network of the region.

Whilst it is clearly impossible to produce the above arguments in rigorous form it is suggested that they offer considerable support for the purely aerodynamic results obtained from the model.

It is interesting to examine these results from the point of view of level of lowest inversion. From comparisons 9 and 12 it can be seen that, as would be expected, the agreement between estimated 950 mb direction and observed surface direction improves when low-level inversion cases are removed. From comparisons 2,5,6 and 7 it appears that the model's predictions are best when the lowest inversion is above 750 mb or when there is no inversion, second best when the inversion is in the 750–850 mb layer and worst when inversions below 850 mb are included. These results are reasonable since local effects (other than purely topographical ones) would be expected to become increasingly important with inversions near the surface. Caution must be employed, however, in interpreting results obtained from small numbers of cases.

The final section of this simple analysis is included in order to show the degree of success of the model's predictions when thermal components are ignored, to highlight the need for forecasters to take account of thermal components when using the model's predictions, and finally, to provide a compact conspectus of all the comparisons including seasonal differences.

Fig. 5 compares the model-predicted and observed surface wind directions at the four locations in 1980. The quantity shown is difference in direction (from 0° to 180°). Cases where calm was predicted and occurred are counted as 0° difference. Cases when no wind measurement was recorded (M), wind flow was recorded but the model predicted calm ($X_1$), and where a calm was recorded but the model predicted flow ($X_2$) are shown separately. The diagram shows that the 0° to 30° class was almost always the largest. It can be seen that Akrotiri and Paphos had similar 0° to 30° graphs and that the Larnaca graph had some resemblance to those at the other three locations. The diagram can be summarized as follows:

Percentage occurrence of various types of comparison between model-predicted and observed wind directions.

| Station | 0–30° (1 class) | 40–90° (2 classes) | 100–180° (3 classes) | Wind observed Model calm | Calm observed Model wind | No observation |
|---|---|---|---|---|---|---|
| Nicosia | 31 | 23 | 27 | 17 | 1 | 1 |
| Akrotiri | 41 | 21 | 18 | 15 | 5 | |
| Paphos | 38 | 26 | 7 | 13 | 16 | |
| Larnaca | 25 | 25 | 20 | 12 | 18 | |

Cases when the estimated 950 mb wind direction did not change by more than 20° in 24 hours (for from 24 to 120 hours) were examined. Successive differences between model and observed directions were checked to see whether they reduced (improved) or increased (deteriorated) with time. 303 cases were found of which 131 showed 'improvement', 126 showed 'deterioration' and 46 showed no change. This probably means that local effects involving thermal processes were too strong to allow this test to be made.

**Comments on the flow maps (Figs 3(a)–(i))**

Members of directional groups (here identified by range of wind-tunnel flow direction) have similar characteristics as follows:

010–030° Show a lee trough to the Kyrenia mountains, air flow hugging the Troodos mountains and a confluent area in their lee.
040–050° Show a weak trough in the lee of the Kyrenias, hugging of the Troodos range and confluence downstream of the range.
060–090° Very simple patterns but a tendency for flow to hug the Troodos.
100–130° Very simple patterns but with a tendency for flow to hug the Troodos and for a slight perturbation in the lee of the Kyrenia range.
140–170° Very simple patterns with range-hugging but with a suggestion of a lee trough north of the Kyrenia range.
180–190° Southerlies established north of the Kyrenia range with signs of some perturbation across the range itself. Otherwise a simple pattern.
200–210° A generally simple pattern but with signs of convergence between Morphou Bay and Nicosia.
220–290° Very simple patterns.
300–360° Simple flow patterns. The lee trough to the Kyrenias becomes re-established. A zone of confluent winds south-east to south of the Troodos moves west or east as the main (950 mb) flow veers or backs.

Therefore only nine of the 2000 m inversion streamline maps, out of a total of 36, have been shown.

The above features are all familiar to meteorologists. The service provided by the model system is that of offering evidence that the effects operate strongly over and around Cyprus. No physically unreasonable or unrealistic patterns appear.

**Conclusion**

Absolute verification of the results obtained from the model is, probably, possible only with a very large and meticulously scaled model, a huge wind-tunnel and sophisticated ancillary equipment. The analysis of real data, presented here, offers considerable support to the model's predictions but can not be claimed as a thorough verification. The model demonstrates patterns which would be expected from first principle physical reasoning. The large-scale roughness of the model island is broadly correct because care was taken to incorporate major peaks, valleys and changes of slope. Any relationship between the small-scale roughness of the model and of the island itself is mainly due to chance. All that can be said is that the plaster was carefully shaped but was smoothed only to the extent necessary to remove unwanted irregularities. The model wind speed and the ten-fold exaggeration of vertical scale were, as explained, consequences of the materials and equipment available. The model and wind-tunnel are crude but are better than an amusing toy. It is probably as good a model system as anyone is likely to have the opportunity to make in the near future under the present-day constraints affecting the interested meteorological agencies.

With no previous experience of wind-tunnel studies the writer was delighted to obtain coherent and apparently meaningful results from so coarse a model. The known occurrance of a zone of indeterminate winds separating a western zone of north-westerlies from an eastern zone of north-easterlies off the south coast of Cyprus was explained to fellow yachtsmen using only the model island and flags, applying a series of winds to the island as a whole, from various northerly points, by blowing! It seems likely that other problem areas could usefully be studied with similar simple and inexpensive equipment.

The important, outstanding practical question is that concerning the usefulness of the model's results to the forecaster working in Cyprus and, indirectly, to forecasters working in other broadly similar locations. The writer would suggest that the results be used as follows. In cases where a short wavelength pressure system is crossing the island quickly the model can offer no more than confirmation that suspected topographical controls are powerful and should be given due weight in forecasting surface winds. Similar remarks apply to occasions when the east–west orientated, seasonal pressure trough of summer is moving quickly northwards or southwards. When the 950 mb flow is expected to remain steady long enough for topographical controls to become established, then, even though the wind veers or backs gently, the forecaster is offered an important component of the resultant surface flow at any place or time.

**Acknowledgement**

The writer has pleasure in thanking the Cyprus Meteorological Service for its excellent, basic topographical map and for providing data for Nicosia and Larnaca, and the Head of Service for his interest and encouragement.

**Reference**

Wales-Smith, B. G. 1984 Diurnal and seasonal trough-induced surface pressure gradients and winds over Cyprus (*Meteorol Mag.* In press).

551.501.75:551.501.81:551.557.4

# Radar wind profiler observations of mesoscale wind systems

By M. A. Shapiro, T. Hample and D. van de Kamp

(NOAA/ERL*/Wave Propagation Laboratory, Boulder, Colorado)

**Summary**

Observations from rawinsondes and UHF and VHF radar wind profilers are used to provide mesoscale contour, cross-sectional and time-series analyses of a sharp trough containing upper-level frontal and jet stream structure. The results demonstrate the great potential value of UHF and VHF profilers for this type of work.

## 1. Introduction

Recent technological advances in UHF–VHF radar wind profiling† represent a major breakthrough in obtaining accurate, low-cost, temporally continuous, high vertical resolution wind profiles. Whereas past reports (e.g. Gage and Balsley 1978; Röttger 1980; Little 1982; Strauch *et al.* 1983) have focused upon instrument design and performance characteristics, the present article presents mesoscale meteorological analyses derived from this new observing technology. Examples depicting a surface front, an upper-level front and its associated jet stream serve to illustrate the potential application of wind profiler networks for describing and forecasting the spatial and temporal evolution of synoptic and mesoscale wind regimes.

## 2. The NOAA wind profiler network

The NOAA Wave Propagation Laboratory maintains a network of one UHF (900 MHz) and four VHF (50 MHz) Profilers. The UHF system is located at Stapleton International Airport, Denver, Colorado; the VHF systems are at Platteville, Cahone, Lay Creek and Fleming, Colorado. The Platteville VHF system (operated jointly with the NOAA Aeronomy Laboratory) is an outdated design that gives wind fields with only 1.5 km vertical resolution and for this reason was not incorporated into the analyses that follow. All profilers are programmed for one profile per hour (an average of 12 individual profiles within the hour) with varying vertical resolution. The UHF system has 100 m resolution from 0.34 km to about 2.56 km above ground level (AGL), 300 m resolution from 1.64 km to about 8.30 km AGL and 900 m resolution between 2.70 km and about 14.00 km AGL. The outlying VHF systems provide wind data with 300 m resolution from 1.69 km to 8.35 km AGL and 900 m resolution between 2.61 km and 17.39 km AGL. Changes in vertical resolution are accomplished by changing the pulse length of the radar.

## 3. The upper-level front and jet stream of 13–14 June 1983

During 13 and 14 June 1983 an unusually strong (for the time of year) trough containing upper-level frontal and jet stream structure passed over the Colorado profiler network. The 12 GMT 300 mb wind analysis for 13 June (Fig. 1) based upon rawinsonde and profiler data shows the $\geqslant$50 m s$^{-1}$ jet stream

---

*NOAA/ERL National Oceanic and Atmospheric Administration/Enviromental Research Laboratories.

†For a recent account see e.g. P. K. James (1980), The WPL Profiler: a new source of mesoscale observations, *Meteorol Mag,* **112**, 229–236.

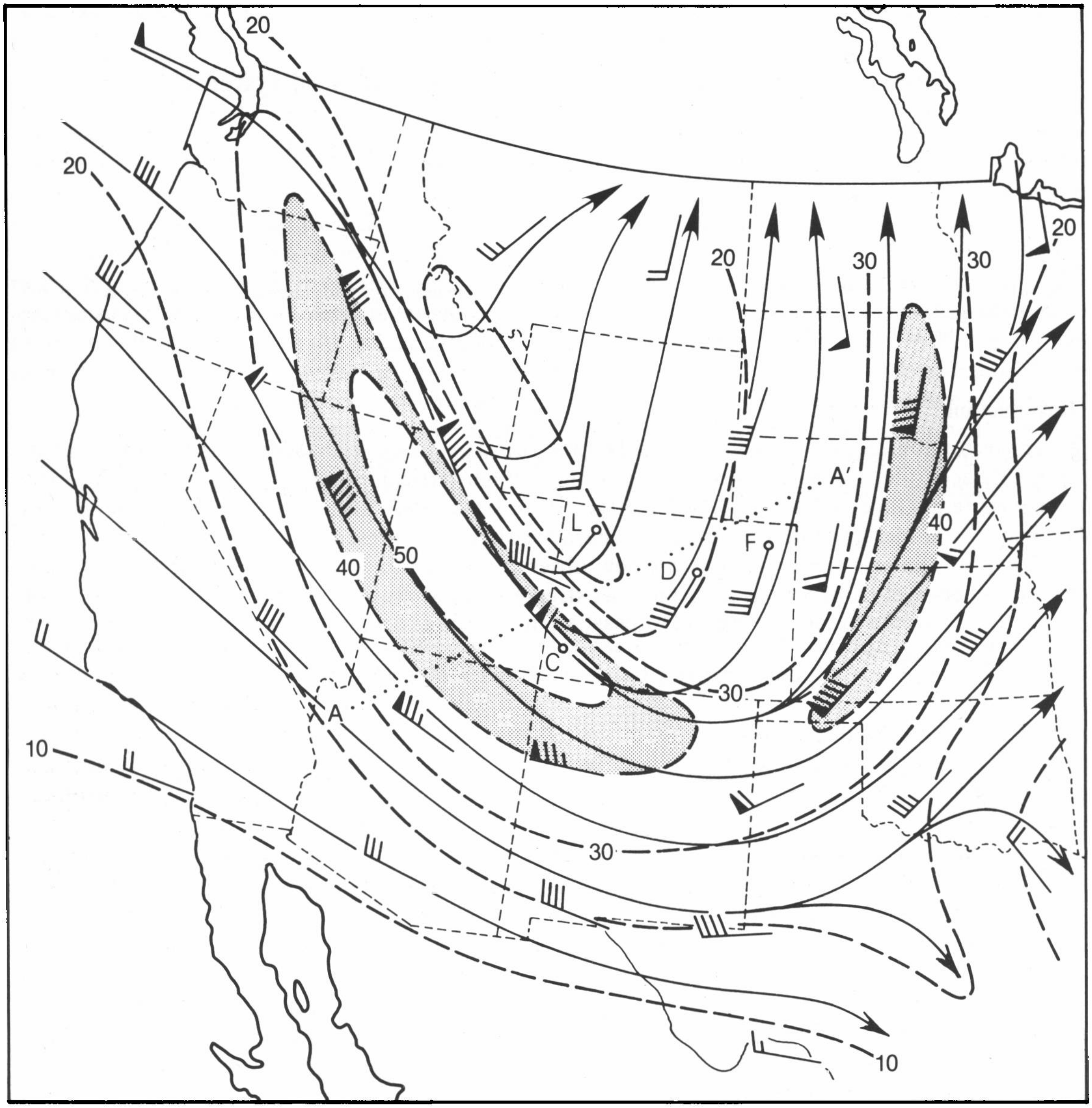


Figure 1. 300 mb wind velocity analysis at 12 GMT 13 June 1983. Wind speed (m $s^{-1}$), dashed lines; streamlines, thin lines; solid pennants = 25 m $s^{-1}$ full feathers = 5 m $s^{-1}$; half feathers = 2.5 m $s^{-1}$. Radar wind profilers are designated by open circles at tip of wind vectors. VHF profilers are located at Fleming (F), Lay Creek (L), and Cahone (C), and the UHF profiler is at Denver (D).

entering south-western Colorado. The Cahone profiler provided a key observation for this analysis, by measuring the 55 m $s^{-1}$ wind speed over the south-west corner of Colorado.

Fig. 2 presents the cross-sectional analysis of wind speed and potential temperature along the line AA′ of Fig. 1 prepared from a composite of conventional rawinsondes and four radar wind profilers. In the analysis, the Cahone profile intercepted the upper-level and jet stream core between the Winslow, Arizona and Grand Junction, Colorado balloon sounding sites. The wind profiles from Lay Creek, Fleming, and Stapleton, and the Denver raob documented the weak wind speeds near the trough axis and the 20 m $s^{-1}$ south-westerly flow in advance of the trough near 300 mb.

After 12 GMT on 13 June, the trough and jet stream (Fig. 1) and front (Fig. 2) continued eastward and passed over the Lay Creek profiler which is located in north-western Colorado. The hourly sequence from Lay Creek (Fig. 3) shows the appearance (after 21 GMT) of the frontal shear layer and its intensification and descent from 9.2 km to 6 km by 10 GMT. The jet core passed overhead at 03 GMT.

## 4. The surface frontal passage on 12 June 1983

On the day before the passage of the upper-level front, a low-level (surface) front passed over the Rocky Mountains and was observed with the high-vertical-resolution Stapleton UHF profiler. The time-series analysis of the 100 m vertical resolution wind profiles (Fig. 4) contains two-hour resolution because computer failure did not permit the usual one-hour data archiving. The analysis shows weak easterly flow below 3 km before 00 GMT 12 June. By 04 GMT, this flow became southerly and increased in speed just before frontal passage. The Stapleton surface winds documented frontal passage at about 0420 GMT. A low-level southerly wind speed maximum appeared above the leading edge of the front between 04 and 06 GMT. After 06 GMT the winds beneath the frontal layer were northerly to north-easterly, becoming easterly up to 2.8 km by 18 GMT.

## 5. Conclusion

The case study analyses illustrate the ability of VHF and UHF wind profilers to document the vertical, horizontal and near-continuous temporal structure of front and jet stream mesoscale windflows. It remains for future construction of continental profiler networks with spatial separation of about 300 km to facilitate the monitoring of upper- and lower-tropospheric wind systems and fronts with temporal continuity comparable with that of present satellite and weather radar observing systems. When compared with the present two soundings per day of operational rawinsondes, the profilers represent a major advance toward obtaining wind observations for improved depiction, physical process diagnosis, very-short-term ($\leqslant$ 6 hour) prediction (statistical and by extrapolation) and numerical prediction ($\geqslant$6 hour) of synoptic-scale and mesoscale weather events. Observations from a network of wind profilers would be especially useful in forecasting the motion and intensity of fronts as they propagate across the United Kingdom and influence the evolution of mesoscale precipitation systems over the region.

## References

Gage, K. S. and Balsley, B. B. 1978 Doppler radar probing of the clear atmosphere. *Bull Am Meteorol Soc,* **59**, 1074–1093.

Little, C. G. 1982 Ground-based remote sensing for meteorological nowcasting. *In:* Browning, K. A.(ed.), Nowcasting. London, Academic Press, 65–86.

Röttger, J. 1980 Reflection and scattering of VHF radar signals from atmospheric refractivity structures. *Radio Sci,* **15**, 259–276.

Strauch, R. G., Decker, M. T. and Hogg, D. C. 1983 Automated profiling of the troposphere. *J Aircraft,* **20**, 359–362.

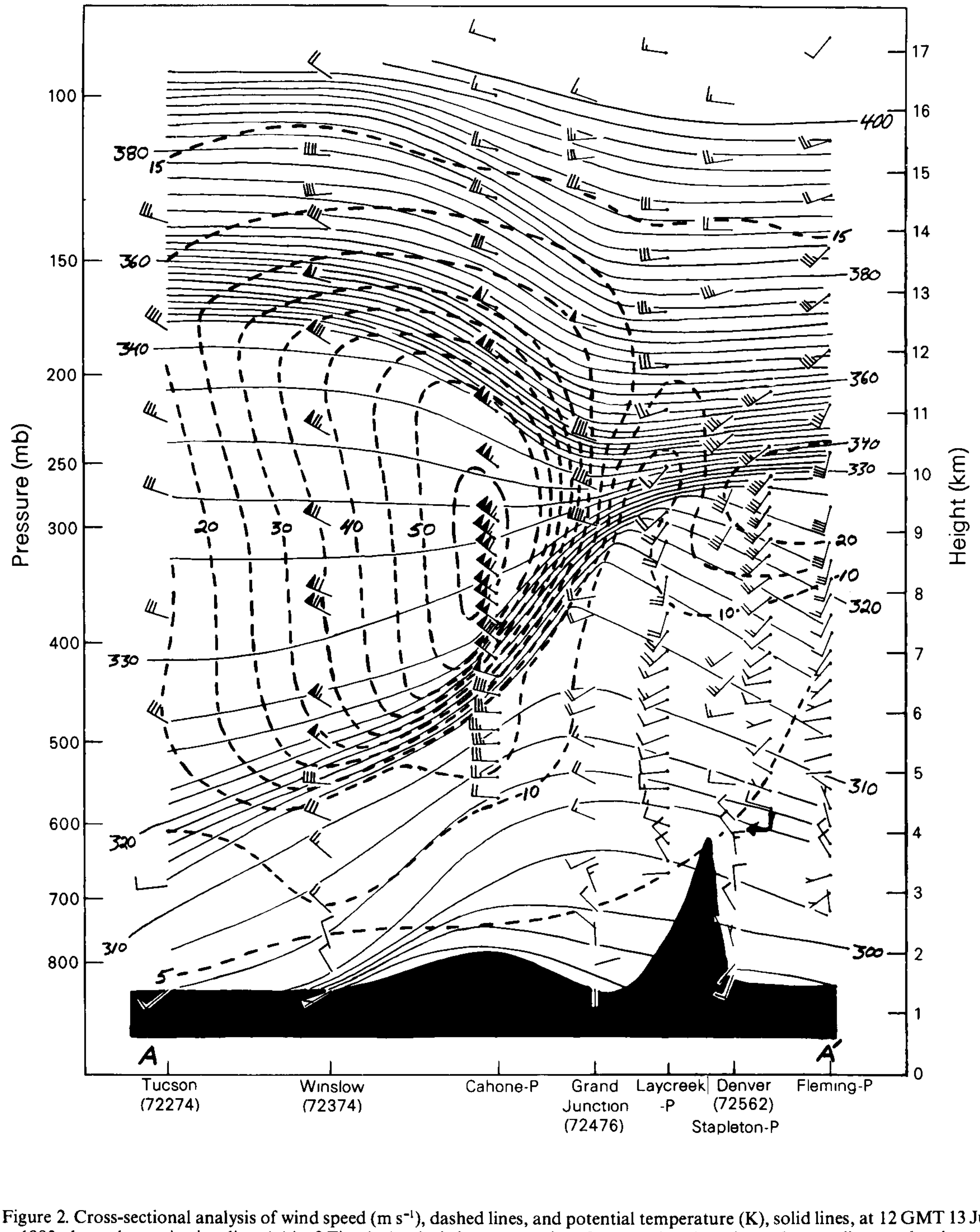


Figure 2. Cross-sectional analysis of wind speed (m $s^{-1}$), dashed lines, and potential temperature (K), solid lines, at 12 GMT 13 June 1983 along the projection line AA′ of Fig. 1. Analysis is a composite of conventional rawinsonde soundings and radar wind profiles. Profiler soundings are designated by the letter P at the horizontal axis. Solid pennants and feathers represent the same values as in Fig. 1.

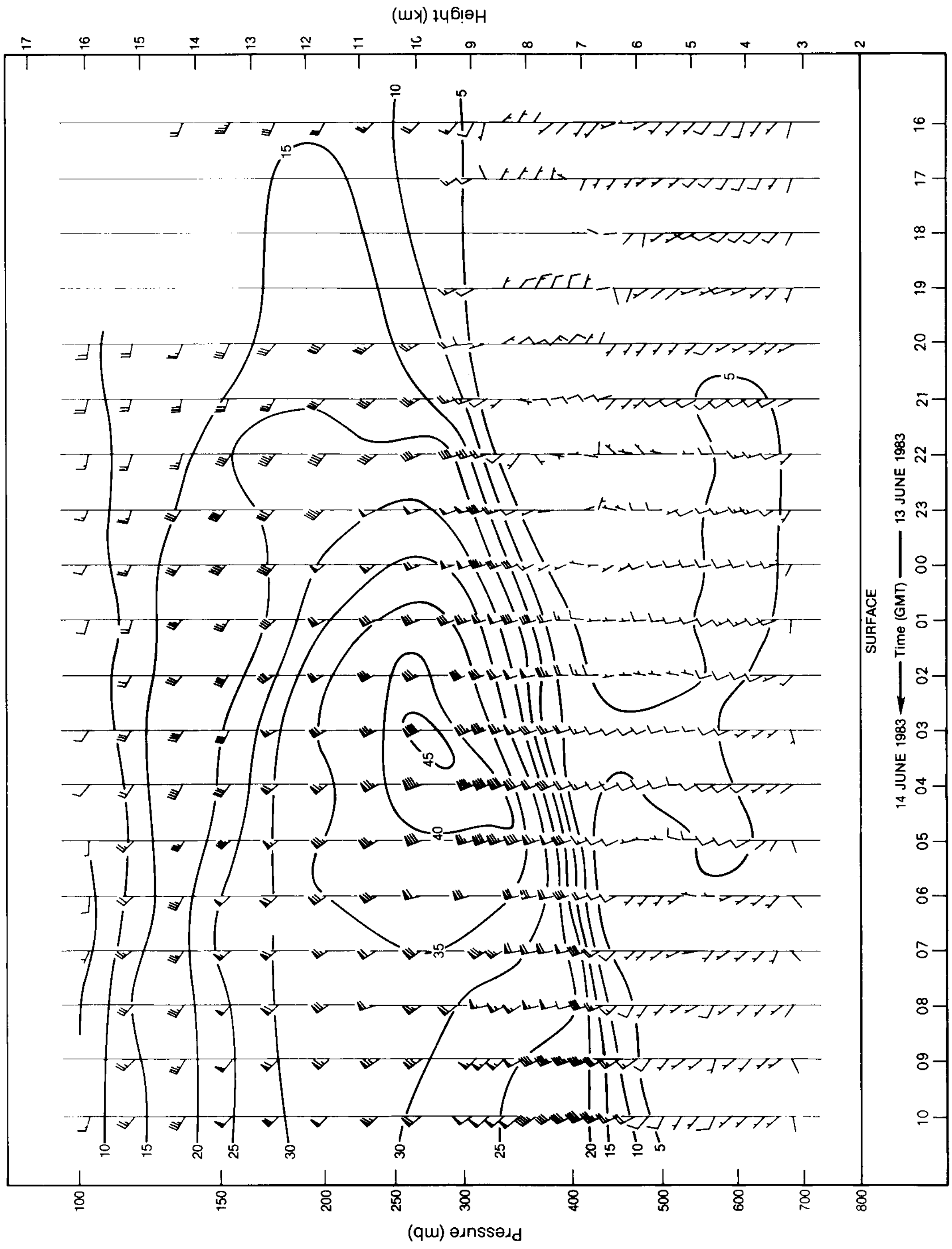


Figure 3. Time-series analysis of wind speed (m $s^{-1}$) and wind vector plot for the Lay Creek, Colorado VHF radar wind profiler between 16 GMT 13 June and 10 GMT 14 June 1983. Solid pennants and feathers represent the same values as in Fig. 1.

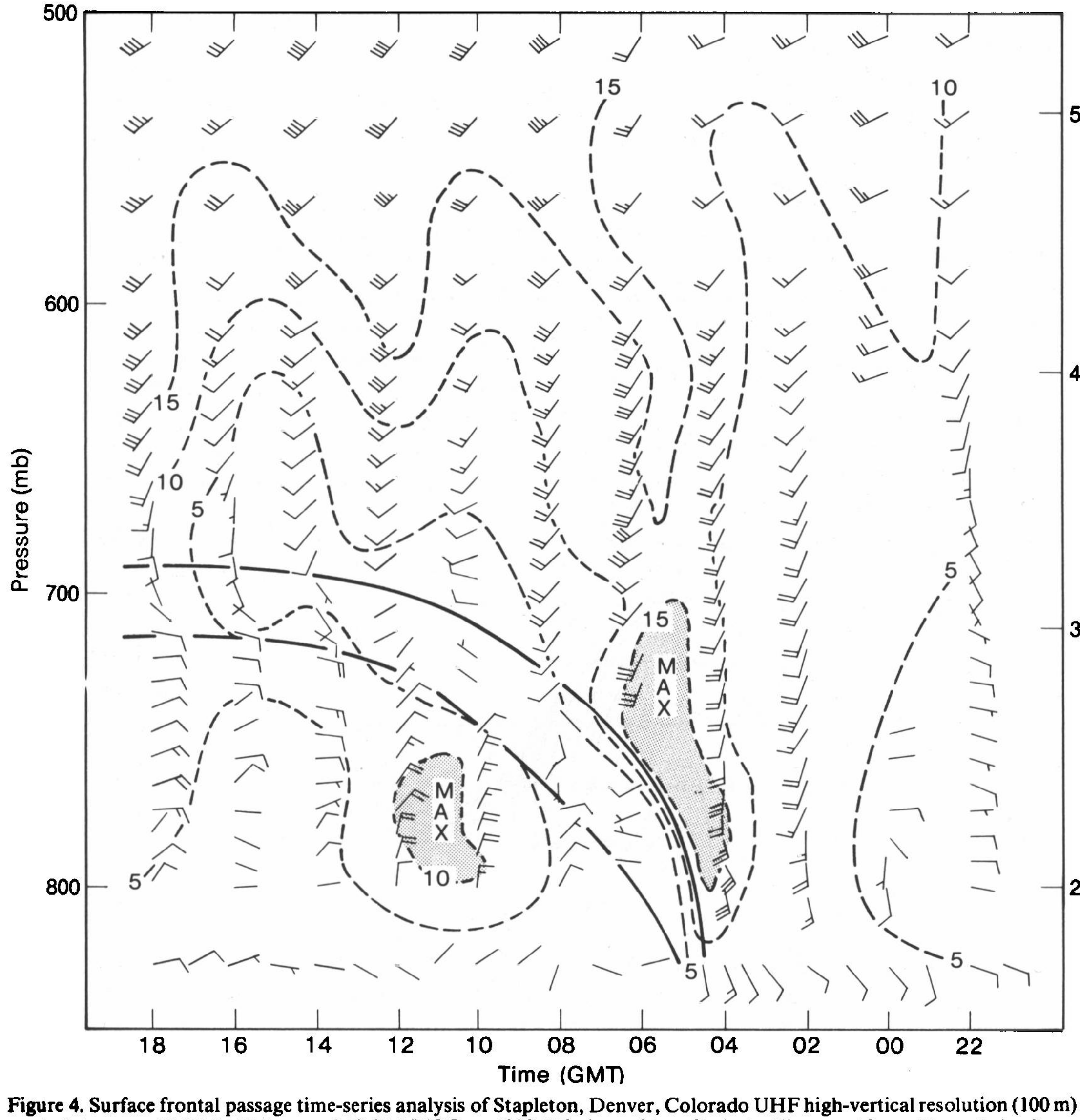


**Figure 4.** Surface frontal passage time-series analysis of Stapleton, Denver, Colorado UHF high-vertical resolution (100 m) radar winds between 22 GMT 11 June and 18 GMT 12 June 1983. Wind speed (m $s^{-1}$), dashed lines, and frontal boundaries, heavy solid lines. Solid pennants and feathers represent the same values as in Fig. 1. Surface winds are plotted at lowest height level.

## Letter to the Editor

### Civil Defence — meteorological advisers to local authorities

I would like to repeat a successful call to your readers that was made in the winter of 1980 for meteorological officers without a likely war role, or those who have recently retired, to volunteer for training as Local Authority Scientific Advisers under a joint Home Office and County Council scheme.

Some twenty meteorological officers volunteered their services in 1981 to various county authorities in England and Scotland. The Royal County of Berkshire was fortunate in securing five, all of whom have become valued Team Leaders with the County and District Councils. Volunteers who make up local authority Scientific Adviser Groups can come from a very wide scientific background, but it has been found that meteorological officers have the highest aptitude and degree of skill for the tasks involved.

Scientific Advisers are responsible for advising the Local Authority Chief Executives in a major civil disaster or in the event of war, including a possible nuclear strike against this country. There is an obvious relevance of meteorological conditions to a developing industrial disaster, e.g. Flixborough, the USA Three Mile Island disaster or the Canadian chemical train derailment and fire at Mississauga in 1980. The prediction of radioactive particle deposition and the spread of toxic gas clouds would have the greatest importance to the enhancement of public survival.

I would therefore like to appeal through your columns to those interested in offering their services to their nearest local authority to contact myself or the County Emergency Planning Officer of their own County Council. Not only qualified meteorological officers are wanted, but any numerate officer who would like to undertake this very worthwhile and humanitarian task. The commitment is not a heavy one and the accent is on the word 'volunteer'.

I will be pleased to answer any queries by letter or telephone and I undertake to pass on any written queries to the appropriate County Emergency Planning Officer, depending on place of work or residence.

J. P. Whittaker
(County Emergency Planning Officer)

*Royal County of Berkshire,*
*County Emergency Planning Team,*
*Shire Hall, Reading.*

## Notes and news

**60 years ago**

The following extract was taken from the *Meteorological Magazine*, June 1924, **59**, 111–112.

### The Meteorological Office Exhibit at Wembley

THE British Empire Exhibition at Wembley was opened by H.M. the King, on April 23rd, with all the pomp and ceremony befitting such an occasion. Unfortunately, the brilliance of the spectacle was somewhat marred by the gloominess of the weather, the sun being obscured by low cloud during the whole ceremony.

The apparent preparedness of the greater part of the Exhibition on the morning of the 23rd was a surprise to those who had visited the grounds only a few days previously. Gardens and trees seemed to have grown up in the night as if by magic, more especially so in the vicinity of H.M. Government Pavilion. In the less conspicuous parts of the grounds, however, there was still much to be done and the annexe to the Government Pavilion in which, according to the official guide, the meteorological exhibit was said to be housed, was still in a state of incompleteness. For reasons over which the Meteorological Office had no control, three weeks elapsed before this part of the building was opened to the public. The entrance to the meteorological section is to be found at the back of the Government Pavilion. It is self-contained, and the walls are hung with specially prepared diagrams illustrating the work of the Office with regard to Weather Forecasting, Climatology, Marine Meteorology, Upper Air Investigations and British Rainfall. Numerous instruments used in meteorological work are on view, amongst these being a Dines Pressure Tube Anemograph, which gives a continuous record of the speed and direction of the wind over the building. There is also an Autographic Rain Gauge to show the intensity of rainfall. In a glass bell is exhibited a specimen of a Balloon Meteorograph, together with a large working model of the same instrument. [So reliable is this instrument in use that in spite of its small size, it can record temperature without an error of more than one degree centigrade, and pressure to within a few millimetres of mercury. The record is inscribed on a small piece of silvered plate about the size of a postage stamp and has to be deciphered by the aid of a microscope].

The preparation of forecasts is demonstrated by members of the Meteorological Office Staff who are on duty there. By means of a wireless installation, data from a great part of the Northern Hemisphere are collected. These are plotted on weather maps and deductions are drawn regarding the coming weather. Two large weather charts, each measuring 10 feet by 9 feet are to be seen in the main building near the front entrance, one of the western part of Europe and the other of a large part of the Northern Hemisphere extending from America to Russia. The chart for western Europe is drawn twice daily, for 7h. and for 13h., and that for the Northern Hemisphere once daily, so that visitors may see the current meteorological situation and at the same time realise the rapidity with which meteorological data are collected from very wide areas.

On May 14th, Their Majesties the King and Queen, accompanied by Their Majesties the King and Queen of Roumania, honoured the Meteorological Section with a visit. The Royal Party were received by Dr. G. C. Simpson, C.B.E., F.R.S., Director of the Meteorological Office, and inspected the exhibit with much interest. The King was particularly interested in the current weather map and in the meteorological log which was kept on board H.M.S. "Thrush," when His Majesty, as Prince George, was in command of that vessel. His Majesty immediately recalled the name of the officer who was responsible for the entries.

Judging from the interest shown by the numerous visitors who inspect the exhibit it would appear that the importance of meteorology is being increasingly recognised by the general public.

## Call for papers for the WMO* technical conference on urban climatology and its applications with special regard to tropical areas

Urbanization is proceeding with great rapidity in the developing (tropical) world, including the growth of some extremely large cities. Population pressures are great but resources are limited. This may lead to a deterioration of environmental conditions for a large proportion of mankind. However, if simple climatic principles are incorporated in the plans of these settlements they can be made safer, healthier, more comfortable and efficient.

In order to accomplish this it is necessary to gather the available expertise in urban, applied, and tropical climatology to review existing knowledge, consider its relevance to the design and operation of tropical cities and to formulate the most effective means of ensuring its use.

*WMO World Meteorological Organization

These are the objectives of the WMO technical conference on urban climatology and its applications with special regard to tropical areas, which is co-sponsored by the World Health Organization. The conference will be held in Mexico City from November 26 to 30, 1984. Topics of relevance to the meeting include all aspects of urban climatology (e.g. processes, effects, models, methods and case studies) especially those relating urban applications (e.g. hazards, health, comfort, air pollution, energy/water conservation and use) to urban planning (e.g. climate factors in the siting, layout and operation of settlements) and to tropical locations.

Papers are invited on the above topics, and abstracts (less than 500 words) should be sent by July 15, 1984 to:

Professor T. R. Oke
c/o World Climate Programme Department
World Meteorological Organization
41, Giuseppe-Motta
Case postale No. 5
CH-1211 Geneva 20
Switzerland

It is intended that the conference will include considerable discussion amongst the participants. Therefore only those papers deemed most important to the objectives of the meeting will be selected for presentation in the main sessions. Provision will be made for the others to be presented as short lectures or as posters (please indicate your preference). The conference will be conducted in English, French, Spanish and Russian. Abstracts may be submitted in any of these languages.

## Reviews

*Catalogue of European industrial capabilities in remote sensing.* 250mm × 175mm, pp. x + 310, *illus.* A. A. Balkena, Rotterdam, 1982. Price £13.00.

The aim of this catalogue as stated in the preamble is to provide information on equipment, services and design capabilities available from European companies in order to support earth observation campaigns.

The initiative for the catalogue comes from an international association called EUROSPACE, which has been set up by some 80 European aerospace and electronic firms. The declared aim of EUROSPACE is the promotion of European space activities.

A short introductory section (incorrectly titled 'The theory of remote sensing') categorizes sensors and platforms, and outlines data handling facilities. After a brief section on European-related remote sensing activities, the various governmental organizations involved in this field and their remote sensing activities are detailed. The next two sections form the main bulk of the catalogue. These are specification type descriptions of the equipment or service available and a description of the activities and potential activities of some 80 European companies (presumably mainly the sponsors of EUROSPACE). The final section consists of 24 preformatted blank 'Update' pages.

This catalogue is a useful availability guide for those persons planning remote sensing exercises on any scale from elaborate field experiments to extraction of specific data from a communal facility (though I would also have expected their organizations to have received a complimentary copy). It is however unlikely to be of much interest to the more general reader of the Meteorological Magazine.

D. R. Pick

*Geophysical fluid dynamics*, by Joseph Pedlosky. 150 mm × 235 mm, pp. xii + 624, *illus.* Springer-Verlag, New York, Heidelberg, Berlin, 1982. Price DM 63.00, approx. US $26.30.

This book is a paperback version of an original hardcover edition (published in 1979). That original has already become a standard, if not a classic, in its field, and the availability of a paperback edition will be generally welcomed. Pedlosky's themes are the derivation and analysis of mathematical models of nearly geostrophic motion in the atmosphere and oceans; and the text is aimed at those engaged — or preparing to engage — in research into such motion.

Two introductory chapters deal with basic matters — rotating coordinate frames, vorticity and geostrophy, for example. The discussion of vorticity (and associated theorems) is the highlight here. In Chapter 3, the notion of quasi-geostrophic approximation is thoroughly explored in the simple case of divergent barotropic flow. Poincaré and Kelvin waves are examined before the main subject, the Rossby wave, is introduced, the equivalence (in barotropic flow) of planetary vorticity gradients and sloping lower boundaries being clearly indicated. Chapter 4 contains a useful treatment of viscous boundary layers and their effects on barotropic flow. Chapter 5 deals with homogeneous models of the wind-driven oceanic circulation, and illustrates the concepts and techniques introduced in the previous two chapters. Quasi-geostrophic approximation for the case of baroclinic flow on a sphere is treated in Chapter 6. This leads to the important approximate potential vorticity equations of geostrophic dynamics. Aspects and applications examined include forced stationary waves, wave/mean interaction, layer models and thermocline modelling. Instability theory is considered in Chapter 7. Much attention is given to linear baroclinic problems, but sections on non-linear developments and barotropic and mixed instabilities are also notable. The concluding chapter briefly discusses some ageostrophic phenomena — principally continental shelf waves, frontogenesis and equatorial modes.

Throughout, the emphasis is on analytical technique and underlying physical concepts. The inclusion of detailed mathematical derivations will not appeal to all tastes, but is perhaps the most valuable feature of the book. Meteorological and oceanographical theory are inescapably technical subjects, and anyone who would contribute to progress in the field must acquire particular analytical skills. For those doing research into geostrophic motion in the atmosphere and oceans, Pedlosky's book is an invaluable aid to the learning and refinement of these skills. Its philosophy, admirably, is that of the workshop manual rather than the sales brochure.

Given such a realistic approach, exercises and examples would not have seemed out of place — but there are none. Perhaps an opportunity has been missed here: carefully drafted exercises could have served the dual purpose of challenging the reader and extending the scope of the text. Many important topics are indeed not covered — and the omissions will be felt more acutely by meteorologists than by oceanographers. Acoustic modes are not examined, and hardly any attention is paid to the special coordinate systems which are commonly used in meteorological dynamics. Internal gravity waves and adjustment to geostrophic equilibrium are also not covered. The concern with quasi-geostrophic dynamics is so great that the derivation (in Chapter 6) of the relevant equations from the original, unapproximated forms does not pause to recognize the hydrostatic primitive equations! Neither is much said about the observed atmospheric circulation, beyond what is necessary to introduce theoretical developments. Sadly, these omissions may deter many meteorologists — especially numerical modellers — from studying the book and assimilating the valuable material that it contains.

A strange feature is the almost total lack of reference to laboratory experiments on rotating flow. While it can be easily appreciated that a thorough discussion would have been long and perhaps diversionary, the presentation would surely have been eased in places by brief consideration of simple laboratory systems. This is especially so in Chapter 4 (which in fact contains much material that is helpful in the analysis of laboratory flows).

Inevitably, developments since 1979 make the book appear outdated in a few respects. Thus the recent interest in atmospheric blocking, and the general question of the maintenance of zonal asymmetries in the time-averaged flow, are not anticipated. However, the emphasis of the text on concepts and techniques equips it well to maintain underlying relevance to recent or foreseeable developments. A good illustration is the treatment of wave kinematics given in Chapter 3: a lucid exposition of group velocity and related quantities here provides a useful starting point for anyone wishing to follow current developments in Rossby wave propagation theory. Again, the central theoretical importance of potential vorticity — which becomes ever more apparent — is stressed in Chapters 6 and 7.

One elementary notion which is given inadequate attention is that of the apparent vertical. In Chapter 2, gravitational and centrifugal potential are combined in the usual way, but without comment that the direction of the implied vertical then depends on the rotation rate of the chosen coordinate system. The absence of Doppler-shift properties in rotating flows, which is noted for the barotropic case in Chapter 3, is intimately related to this conceptually important feature. The appearance of the 'non-Doppler effect' in baroclinic flows is obscured in Chapter 6 because the horizontal boundary conditions are not considered in the appropriate parametric limit.

The presentation of the text is good. Clearly laid out equations, in conjunction with a familiar and reasonable notation, greatly ease the task of the serious reader. Intending purchasers should be warned, however, that pages 437–468 were missing from the review copy.

Pedlosky's book can be recommended to everyone working in dynamical meteorology or oceanography — students and professional researchers alike. It is not, nor is it intended to be, about general circulation theory or numerical modelling strategy and method. It is a specialized text which sets out to illuminate the fundamental concepts and techniques of geophysical fluid dynamics, and is highly successful in that endeavour.

A. A. White

## Books received

*Consequences of climatic change*, edited by Catherine Delano Smith and Martin Parry (Department of Geography, Nottingham University, 1981. £3.50) is a collection of papers as a consequence of a conference of the Historical Geography Research Group of the Institute of British Geographers convened at the University of Nottingham in July 1980. These papers have been published as an attempt to link two extremities of the research spectrum — the archaeological and the climatological — in the context of climatic change.

*Atmosphere, weather and climate*, by R. G. Barry and R. J. Chorley (London and New York, Methuen & Co. Ltd., 1982. £6.50 paperback, £14.50 hardback) is the fourth edition of this book first published in 1968. Important changes to the present edition include substantial rewriting of the chapters on 'Small-scale climates'; the addition of chapter summaries; the updating and standardization of units; the addition of more than 30 figures and plates; and changes to material on solar radiation, thunderstorm mechanics and drought, the characteristics of mesoscale rainfall systems and tornado structures, and the climatic features of disturbances occurring within continental high pressure cells.

*World-climates: with tables of climatic data and practical suggestions*, by Willy Rudloff (*Books of the Journal Naturwissenschaftliche Rundschau*. Stuttgart, Wissenschaftliche Verlagsgesellschaft mbH, 1981. DM 180) contains 50 figures, 1474 climatic tables and 116 hygrothermal diagrams as well as other tables and reviews and is aimed at the general public and tourism for a work on climatology suitable for practical use. The introductory chapters provide information on weather and climate, the global atmospheric circulation, bioclimatic relations, and a classification of climate which the author considers a revised and consistent development of a climate classification system published in 1931 in the second edition of Köppen's *Outlines of climatology*.

*Finite-difference techniques for vectorized fluid dynamics calculations*, edited by David L. Book (New York, Heidelberg and Berlin, Springer-Verlag, 1981. DM 72) is from the *Springer series in computational physics*. The book describes several finite-difference techniques developed recently for the numerical solution of fluid equations. Both convective (hyperbolic) and elliptic (of Poisson's type) equations are discussed. The book is intended for specialists in computational fluid dynamics and related subjects. It includes examples, applications and source listings of program modules in Fortran embodying the methods.

*Evaporation into the atmosphere. Theory, history, and applications*, by Wilfred H. Brutsaert (Dordrecht, Boston and London, D. Reidel Publishing Co., 1982. Dfl 80) is the first in a series entitled *Environmental fluid mechanics* intended for professional scientists and engineers who apply their scientific knowledge to practical goals. An introductory chapter provides an account of the history of the theories on evaporation, the central part deals with the conceptualization and the mathematical formulation of water vapour transport in the lower atmosphere, while the final chapters provide a survey of currently available techniques for measuring and calculating the rate of evaporation.

---

Mr E. W. C. Harris, Librarian of the National Meteorological Library, being presented on 16 February 1984 by Lt. Col R. Wright, USAF, with a 28th Weather Squadron plaque in recognition of the assistance given by the library to the USAF Air Weather Service.

THE METEOROLOGICAL MAGAZINE

No. 1343 June 1984 Vol. 113

## CONTENTS



---

NOTICES

It is requested that all books for review and communications for the Editor be addressed to the Director-General, Meteorological Office, London Road, Bracknell, Berkshire RG12 2SZ and marked 'For Meteorological Magazine'.

The responsibility for facts and opinions expressed in the signed articles and letters published in this magazine rests with their respective authors.

Applications for postal subscriptions should be made to HMSO, PO Box 276, London SW8 5DT.

Complete volumes of 'Meteorological Magazine' beginning with Volume 54 are now available in microfilm form from University Microfilms International, 18 Bedford Row, London WC1R 4EJ, England.

Full-size reprints of out-of-print issues are obtainable from Johnson Reprint Co. Ltd, 24–28 Oval Road, London NW1 7DX, England.

Please write to Kraus Microfiche, Rte 100, Millwood, NY 10546, USA, for information concerning microfiche issues.

---



Printed in the UK
and published by
HER MAJESTY'S STATIONERY OFFICE

**£2.20 monthly**

**Annual subscription £26.50 including postage**

Dd. 737126 C15 6/84

ISBN 0 11 727234 5
ISSN 0026-1149