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JOURNAL OF METEOROLOGY

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TEMPORAL FLUCTUATIONS OF ANNUAL RAINFALL IN NICOSIA, CYPRUS

By A. A. FLOCAS

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Abstract: Trends and periodicities in the annual rainfall for Nicosia, Cyprus, on the basis of rainfall records of 87 years, were analysed primarily by using the Mann-Kendall rank method, low-pass filter technique and power spectrum analysis. Downward trends were found in the recent annual rainfall series. An interval of approximately 5-15 years was found to be the dominant period of the annual fluctuations. The prominent cycles revealed by the spectral analysis were 2.5-2.8 years, 3.2-3.6 years and 4.1-4.5 years. The larger observed cycles (8.3-9.7 years, 58 or more years) were weak at the 0.05 or 0.10 significance level.

INTRODUCTION

During the past three decades much research work has been done in various countries on trends and fluctuations of rainfall, based on long series of instrumental records. This is because some knowledge of such fluctuations is essential in solving various problems dealing with irrigation, crop yield and water supply for domestic and industrial uses. Among the many researchers who have analysed time series of rainfall are Suzuki (1968), Jagannathan et al. (1973), Smith (1974), Zangvil (1979), Taboni (1981), Repapis (1984), Brazdil et al. (1985) and Maheras (1987).

In the Eastern Mediterranean which is located on the northern flanks of the vast Sahara-Arabian deserts the problem of climatic fluctuations has engaged the attention of a few research workers. Zangvil (1979) has investigated the precipitation in Jerusalem and found periodicities of 3.0 to 3.3 years and secondary peaks near 2.2 and 6.0 years. He suggested that the peak of the 3.0-3.3 years, as the one at 6.0 years, are probably associated with the widely recognized global oscillation called Southern Oscillation and the peak at 2.2 years with Quasi Biennial Oscillation (QBO). Melice and Wendler (1984) also investigated the precipitation data of the semi-desert regions of Tunisia and found periodicities associated with QBO. Repapis (1984) investigated the temporal fluctuations of precipitation over Greece and found significant peaks at periods of about 2.0 and 3.0 years in the annual rainfall data which are associated with QBO and Southern Oscillation, respectively.

From the above it is obvious that the periodicities in the rainfall which were found in various regions located north of the vast Sahara-Arabian desert, are associated with the recognized global oscillations namely Southern Oscillation and the QBO.

The object of the present study is to examine trends and cycles in the annual rainfall total amounts in Cyprus, which is located in the north-east corner of the east Mediterranean basin. Cyprus, zonally, extends approximately between longitudes 32°20'E and 35°5'E and meridionally between latitudes 35°15'N and 34°35'N. The climate of Cyprus is of the Mediterranean type characterized by rainy winters and dry summers. It is believed that an analysis of the variations of rainfall in Cyprus could help the investigation in understanding the mechanism which causes the rainfall fluctuations in the vicinity of deserts.

2. DATA

Although the climatological records over Cyprus do not extend back more than 87 years, an investigation of possible rainfall variations has been attempted. In Cyprus, there is only one meteorological station, Nicosia, with fairly long records of rainfall. For this reason, the data used for this study comprise the time series of annual rainfall amounts in Nicosia. The period of observation starts in 1900 and ends in 1986, so that the total number of data used is 87 years.

Because a trend in a climatological series may arise from a heterogeneity in the data, in this study the homogeneity of the rainfall time series used has been examined by using the run test (Thom, 1966). This is a sensitive non-parametric test and its results indicated no appreciable heterogeneity in the used rainfall data.

In order to apply statistical tests to a time series it is essential to know the nature of the frequency distribution. The frequency distribution of the annual total rainfall amounts were tested for normality using Fisher's g_1 and g_2 statistics compared with their respective standard errors (SE). The test for normality at the 95 per cent confidence level requires that the values of $g_1/SE(g_1)$ and $g_2/SE(g_2)$ should be less than 1.96. The annual rainfall amounts at the station of Nicosia fulfil this criterion (Table 1).

3. ANALYSIS AND RESULTS

a. Basic statistics

The basic parameters related to the rainfall station of Nicosia are given in Table 1. The mean annual rainfall from 1900 to 1986 was 356.1mm and the standard deviation 94.7mm. The wettest year on record, 1913 had a fall of 638.0 and the

TABLE 1. Some basic statistics of the Nicosia annual rainfall data, 1900-1986.

Average mm	Lowest mm	Percent of average	Highest mm	Percent of average	standard deviation	$g_1/SE(g_1)$	$g_2/SE(g_2)$
356.1	146.6	41	638.0	179	94.7mm	0.346	-0.284

driest year, 1915, received only 146.6mm. These extreme annual totals represent a range from 179 to 41 percent of the long period mean. Compared with the station of Jerusalem this is not a large variation. At Jerusalem, where the mean for the period 1846 to 1964 was 560mm, the wettest year received 199 per cent of the long-period mean and the driest year 35 per cent (Jordan, 1964).

Departures of rainfall from the normal were calculated and these percentage

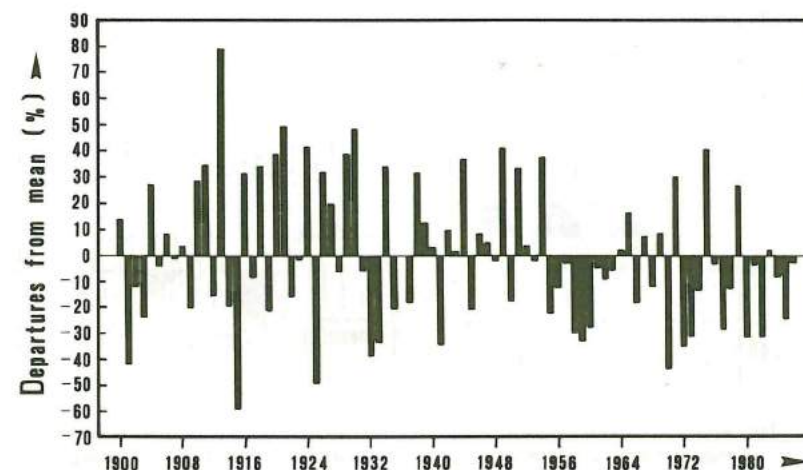


Fig.1: The annual rainfall in percentage departure from the long-term average at Nicosia.

departures were averaged for each year for which records were available in the period 1900-1986. The long-term annual series are shown in Figure 1.

b. Trends.

To examine trends in the annual rainfall series, both graphical and statistical approaches have been employed.

1. Graphical Approach

Under this method, the annual rainfall series was smoothed by binomial coefficients (W.M.O., 1966) and the resulting series was displayed graphically. The weights applied in the filtering process were 0.22 for year i , 0.20 for the years $i \pm 1$, 0.12 for the years $i \pm 2$, 0.05 for the years $i \pm 3$, and 0.02 for the years $i \pm 4$. This filter removes almost all fluctuations with periods shorter than 5 years. In addition, a simple statistical test used by Smith (1974) was applied. In accordance to this test, those fluctuations in the running-mean curves with amplitudes of less than twice the standard error (SE) of the long-term mean are considered as not being statistically significant. The filtered form of the series is shown in Figure 2. The generalized trend in the annual rainfall series was a slight increasing trend at the beginning of the period, followed by a decreasing trend. The most pronounced features of this running mean are the significant above-average annual rainfall total amounts which occurred from 1910-1914, 1917-1931 and 1947-1954. The other outstanding features are on the significant below-average rainfall amounts experienced in 1955-1961, 1970-1974 and from 1980 onwards. It is not possible to make any assumption regarding the cause of these very large long-term fluctuations. However, it is interesting to note the existence of a general similarity between the 10-year running mean of Nicosia's rainfall and the 10-year running mean of Jerusalem's rainfall. These variations are almost in phase for both regions. This suggests that variations in precipitation with a period of over 5 years originate in both Jerusalem and Nicosia in the same global climatic controls.

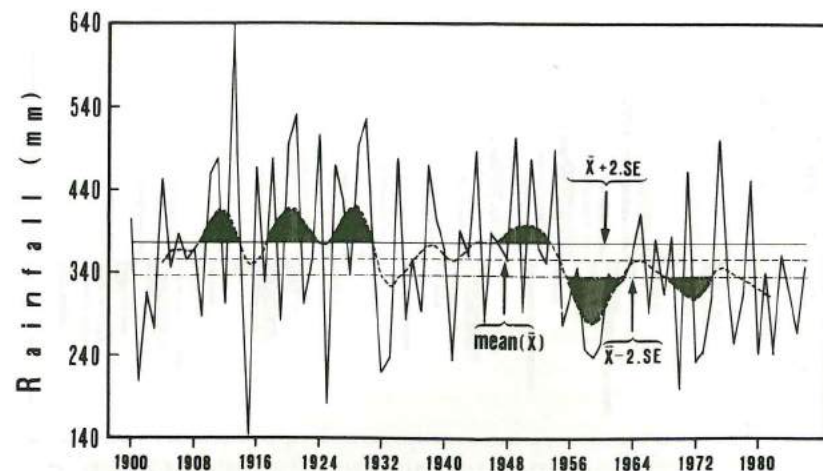


Fig.2: The original (solid line) and the smoothed (dashed line) rainfall series at Nicosia (1900-1986). Shaded areas indicate significant periods.

2. Statistical approach.

It is realized that the visual determination of trends from smoothed graphs is very subjective depending on individual judgment. An objective statistical method was therefore used to investigate further trends in the annual rainfall data. The presence of some form of trend in climatological data may be examined by using the Mann-Kendall rank statistic, r , (Kendall and Stuart, 1961).

In view of the above-recognized decrease of rainfall that took place in the second half of the present century, trends were analysed over the following periods at Nicosia: from the beginning of the record to 1944, 1945-1986, and for the whole period of the record.

The trend analyses were subjected to the Mann-Kendall rank statistic, r , when the most likely alternative to randomness is a linear or non-linear trend. Table 2 gives the r values for the annual rainfall series of Nicosia, and the 95 and 99 per cent significance levels are suitably marked.

TABLE 2. Mann-Kendall rank statistics, r .

Station	1900-1944	1945-1986	1900-1986
Nicosia	+0.041	-0.835**	-0.121*
* significant at 95 per cent level			
** significant at 99 per cent level			

Generally speaking most of the trends are negative, indicating a general tendency to decreasing annual rainfall total amounts over the time periods considered. The annual rainfall totals show these decreasing trends to be highly significant (99% significance level) for the period 1945-1986 and significant (95% significance level) for the whole period of 1900-1986. For the period of 1900-1944 there is a slight tendency to an increase in the annual rainfall amounts but not at any significant level (90%, 95%, 99%).

c. Power spectra.

The spectral analysis of the unfiltered time series of the annual total rainfall amounts was made following the Blackman-Tukey method as outlined in *Climatic change* (W.M.O., 1966). The maximum lag time used was 29. The resulting spectra for the annual rainfall series of Nicosia are shown in Figure 3. The time series analysis of the unsmoothed annual data revealed the following features:

1. Lag-one correlation was negative with a large value ($r_1 = -0.181$), this being indicative of short-period oscillations.

2. Spectral analysis results indicated that there were some cycles in the annual rainfall series. The major cycles showing up were 2.0 years, 2.5-2.8 years, 3.2-3.6 years and 4.1-4.5 years. The peaks of these cycles, with the exception of 2.0 years, are significant at 90 per cent. The cycle of 3.2-3.6 years was almost found by Rodhe and Virji (1976), Granger (1977) and Zangvil (1977). In general, longer cycles were also present in the series but these cycles (8.3-9.7 years, infinity - 58.0 years) were not significant at the 0.05 or 0.1 significance level. Also, the Southern Oscillation has been recognized in recent literature as a world-wide phenomenon having a dominant period of 3.0 to 6.0 years (Trenberth, 1976). The rainfall periodicities of 3.2-3.6 years and of 4.1-4.5 years found at Nicosia are in accordance with that.

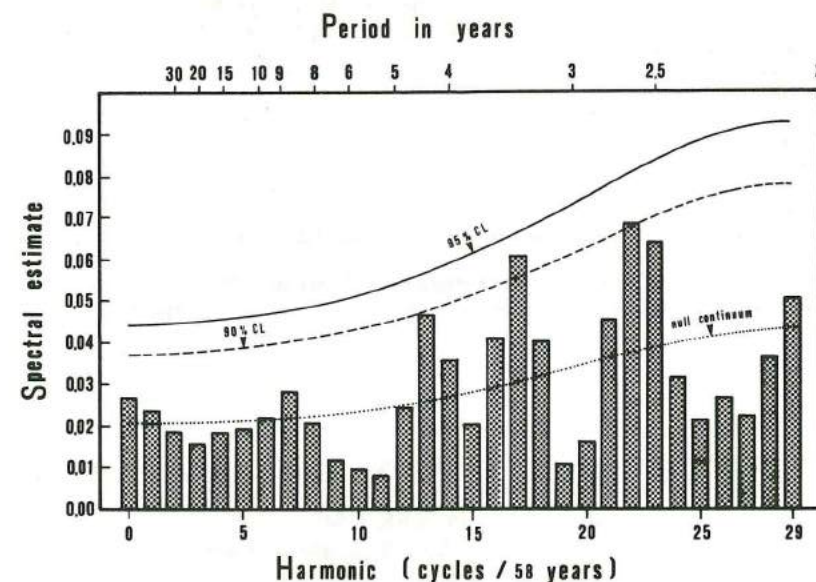


Fig.3: Power spectrum of annual rainfall amounts at Nicosia (1900-1986).

CONCLUSIONS

A series of 87 annual rainfall data of Nicosia-Cyprus has been examined to detect possible short and long-term fluctuations and periodicities. Tests of normality indicate that the annual distribution is normal. The generalized trend in the annual series was a slight increasing trend at the beginning of the period,

followed by a decreasing trend. The filtered series revealed that major peaks affecting annual distribution occurred around 1911, 1920, 1927 and 1950 and major troughs around 1932, 1957-1958, 1972 and 1980-1981. Thus the dominant periods of the fluctuations appear to be at intervals of approximately 5-15 years.

The power spectrum analysis indicated a dominant peak at a period of 3.2-3.6 years and two secondary peaks at 2.5-2.8 years and 4.1-4.5 years. The peak at 3.2-3.6 years and 4.1-4.5 years may be associated with the widely recognized global oscillation called the southern oscillation.

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THE WEATHER OF PEPYS, 1660-1669: PART 3

By the late DEREK J. SCHOVE
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Abstract: The third part of this series of four articles, published posthumously, covers the period from the winter of 1666/67 to spring 1668.

WINTER 1666-1667. COLD. VERY COLD MIDWINTER. THAMES ICE.

Pepys begins his diary for the year 1667 with the words: 'Lay long, being a bitter, cold frosty day, the frost being now grown old, and the Thames covered with ice'. Possibly there was some exaggeration, although even on 2 January Goad confirms with 'Ice on Thames' and on the 3rd 'Ice in bread'. On the 5th de Repas

wrote '... the most part of the Thames is frozen and it is thought one may venture over (on foot) within two days' (HMC 29 III). On the 6th Josselin wrote 'frost continues' and on the 7th Pepys again 'Lay long in bed' but the thaw came on the 9th and on the 11th he wrote 'Up, being troubled at my being found abed a-days by all sorts of people', and by the end of the month he was out in the garden in the moonlight singing.

Apart from this severe frost of December and early January the winter in the strict sense was not as abnormally cold as Pepys comments have suggested, the second spell of snow and cold being here relegated to 'Spring'. The high price of coal (vii, 401, n.5) was not due to profiteering: the Second Dutch War (1664/67) had too often held up the Newcastle ships.

SPRING 1667: COLD BACKWARD DRY SPRING

Almost at the beginning of Spring, on 26 February in the Old Style calendar, a severe easterly spell affected England. On the 27th Pepys reports 'it being bitter cold weather again, after all our warm weather ...' and in Essex the following day Josselin records 'a wonderful deepe calme snow'. On 6 March when coal was so expensive, Pepys tells us 'the King saying today that it was the coldest day he ever knew in England'. The next day the 7th was reckoned by all people the coldest day that ever was remembered in England and on the 10th Josselin writes 'the frost continueth beyond measure vehement with bitter northeast winds and a wonderfull deep snow with mighty drifts'; Pepys on that day does not mention the weather but, hoarse with a cold, wrote 'lay in bed till noon and then up to my chamber with a good fire'. Even on the 16th when the thaw began Goad reports 'much ice' on the Thames. Josselin too claims that 'all people said it was the bitterest March in their remembrance ...'.

The cold March is also documented in Denmark and Holland. No thermometrical evidence has been found, but some days in the winters of 1684 and probably 1671 (cf. 1670, Dec.26 O.S.), 1621, 1656 and 1658 were likely to have been colder. The March winds no doubt made the days seem colder in 1667 than they really were. Certainly, a very backward Spring is indicated by Evelyn's comment on 4 April (14th in our modern calendar) 'The cold so intense - hardly a leaf on a tree'. This Spring is thus comparable with that of 1695, Manley's (1974) means being only 6°C for the three-month period.

April was very dry and often cold and there was a backward Spring. On 21 April Pepys tells us 'it raining a little which is mightily welcome, it having not rained in many weeks'. In Oxford on the same day Wood tells a similar story all the month before except on '2 day(s) noe raine fell at all'. Josselin states, 'scarce a shoure in Aprill. Cold and dry to the 19 May'. The continued dry weather is not explicitly noted by Pepys who mentions certain fine days. However, reading between his lines, we may note 'the horrid dust' in the Park on 1 May (when Goad reports 'warm and dry') and the talk on 5 May of 'six or eight fires within these few days'. (cf. also 29 April, viii, 191, no.2 fire engines now being made in England). In Norfolk May was described as 'Strangely cold and dry' (Clarke MS) but in London there were frequent showers (Goad). An abnormal number of butterflies, seen in May, were assumed by contemporaries to be associated with the Spring drought, but Pepys notes neither the butterflies or the drought.

SUMMER 1667: VERY HOT AND DRY

In this summer, in June and July, the easterly winds favoured the Dutch fleet when it came up the Thames and Medway whilst peace negotiations were under way.

The third good summer in succession was even hotter than its predecessors, as the diary implies by Pepys's little personal details. Thus Josselin was to write in mid-June 'May 24 turned hot and dry so til June 16'. Among other reference to heat, Pepys tells us: 26 May: 'Up sooner than usual on Sundays, and to walk, it being exceedingly hot all night (so as this night I begun to leave off my waistcoat this year) and this morning'. (Goad also records a hot night).

On the 31st Pepys writes:

'To the office, where the weather so hot now-a-days that I cannot but sleep before I do any business'.

Again on 20 June:

'To bed, miserable hot weather all night it was'.

On the 28th he tells us that the King and Duke of York were doing their travelling by night 'for coolnesse'.

Finally on 13 July:

'Up pretty betimes, it being mighty hot weather, I lying this night, which I have not done, I believe, since a boy, I am sure not since I had the stone before, with only a rugg and a sheet upon me'.

The hot summers of 1633/39 could possibly have been in Pepys's childhood memories (cf. viii, 175, n.2) for he had been born in 1633.

The hot weather had continued longer than Josselin's original note indicated, and on 23 June it was in Essex still 'hot and dry extreame'. On 30 June Josselin sums up the weekly weather 'God good in sweet dewes' but it was apparently not the heat but her health that prompted Mrs. Pepys' 'making of tea' on the 28th 'for her cold and defluxions'. Later in the year (8 October) in the garden at Audley End Pepys was to 'eat many grapes' another indication of the warmth of the summer.

The first half of July was likewise at Oxford the hottest within living memory, according to Wood and his claim that 'the heat and strong drink' sent several students mad has already been quoted (viii, 356, n.2).

Guns were heard again this summer (7 June. See entry under 8 June) at Bethnal Green when the Dutch fleet, having arrived off Harwich, were preparing for their attack on the Medway.

The dryness of the summer may again be inferred from the incidental remarks of Pepys. He had mentioned rain on 3 May, but until 27 July he makes no further reference to rain or lightning this year. There are again references to the 'way very dusty' (30 May – the edition by Wheatley had 'nasty'), 'dusty weather' (9 July), 'a very fine day . . . only the way dusty' (14 July), 'the way so dusty that one durst not breathe' (17 July) and 'dusty' (18 July). Finally when the rains do come, on 27 July, Pepys makes an explicit statement 'it having not rained, I think, this month before, so as the ground was everywhere so burned and dry as could be; and no travelling in the road or streets in London, for dust'. Josselin refers to the same rain on the 27th adding 'a sweet shoure it was'. For the previous two weeks his comment had been 'a very sad and droughtie season'.

The usual 'colic' was to affect Pepys on 10 October and his wife on the 20th. This could have been due to unripe fruit but was probably another indirect effect of the dryness.

A more sinister aspect of the drought was the fear of another fire, a fear so bad that Pepys anxiously reports how the evidence of children of 12 was accepted to accuse men of deliberately burning houses. Pepys thought the boys were probably justified but added that he was not satisfied with the power 'given to such little boys to take away men's lives' (4 July).

The weather in August with mixed thundery showers and some cool mornings (cf. 11, 16 August), which on the 12th seems to have aided a sexual reconciliation with his wife. Fog every morning from the 4th to the 7th in Goad's record in an unusual feature but Pepys makes no mention of it.

In this summer pressure was high over the British Isles but probably low in N.E. Europe as indicated by the 'monsoonal' summer in Germany and by narrow tree-rings on the Norwegian hillsides. The dryness was noted even in Ireland and Scotland, where 'the grass was gardually burnt up; the victuall whitened before the midst of July and soon rypned by the end of the month' (Law's Diary).

AUTUMN 1667: WET AT FIRST. UNSETTLED.

The unsettled weather continued through the Autumn but Pepys comments are becoming fewer. Once again we have to glean our information by reading between the lines. To start with, on 23 August Pepys is 'all dusty' after leaping out of a coach; a change to 'very foul' weather occurred on 13 September and after that the word 'dusty' is replaced by the word 'dirty' as on the 17th ('mighty dirty'), Josselin lamenting on the 20th 'sad wett season'. Although Pepys mentions moonshine on the 21st he again says 'the way very dirty' and we infer that London did not escape the many thundery showers reported elsewhere (e.g. Norfolk) during this week. On the 23rd it was yet again 'most dirty' and on the 25th after a 'mighty wet day and night' it was 'very dark and dirty'. The last fortnight of September was wet also in Oxford. Further wet days are mentioned in early October in London.

A typical November 'peasouper', as London fogs (cf. Brazell, 1968, Chapter 7) later came to be called, occurred on the 11th. Pepys says merely 'a most cold and foggy, dark, thick day', and Goad confirms 'fog all day' but Wood's description of the traffic chaos (viii, 525) is reminiscent of the twentieth century before the Clean Air Act of 1956.

Pepys was finding the light bad for his eyes this year, but that can hardly explain why he mentions the dark days and omits the snow. The snowstorm at Oxford on the 18th-19th is described by Wood, and Goad confirms that the snow of the 18th was still lying on the 19th.

DECEMBER 1667: WARM, FAIRLY DRY.

Pepys has only six references to the weather of this winter, for there were neither severe frosts nor incessant rain! The diagnosis of the pattern as 'warm and fairly dry' is established on other grounds. The month, in the Old Style sense, was nevertheless wet in Norfolk.

YEAR. ANOTHER DRY EASTERLY YEAR. COLD.

The direction of the wind was seldom mentioned by Pepys even when he was with the fleet but the general continental character of this year can be gauged not only from the cold weather of its first four months but also from the general dryness in N.W. Europe and the wetness in Italy; for this is typical of a year when easterly winds were much more frequent than usual. Indeed, wind records from the 'Downs' are available from this year in the (CSP) State Papers and confirm that NE winds were unusually frequent in both 1667 and 1669.

WINTER 1668: MILD.

We know from Josselin and other writers that the winter was mild, especially in February, and it was also dry in January. Pepys tells us very little about the weather. On Saturday 4 January for instance there was a 'Tempest' according to Goad, but Pepys did not enter up his diary for that date until the 8th (see his comment) and the gale had perhaps by then been forgotten. Pepys mentioned, as did Goad and Josselin, the frost on the 11th, and on 27 January 'weather like the beginning of a frost and the ground dry' but except for the last phrase there is no note of the intervening good weather, which caused Josselin to speak of 'A very dry, calm, warm Jan'. The abnormally warm February (in the Old Style sense) is noted in Norfolk with the words 'strangely warme and a forward Spring' but there are no clues in Pepys that refer to this or the frequent rains. Likewise the gales of 16-18 February, described by Goad and Rugge, are not noted by Pepys who is more concerned with the 'high words' in the House than the high winds outside.

SPRING 1668. FAIRLY COLD. OFTEN WET.

Pepys fails to mention the March comet but he does (ix, 207, n.3) mention the May meteor and indeed he is again beginning to tell us more about the weather. There was a dry period from the 6th or at least 15 March to 3 April, for on 4 April he states 'it had been a dry season for some time . . . mighty dusty' and this is confirmed by Josselin for the three weeks ending 29 March and in Oxford by Wood who on 5 April said 'none for almost 3 weeks before or a month'.

On 6 April Pepys writes 'last night's rain very pleasant and no dust' but the afternoon's rain must have been less pleasant because he wrote 'I was forced to lend the Duke of York my cloak'. The Duke of York, later James II, had two days previously told Pepys his rules for forecasting the weather, but we do not know what these rules were. The beginning of the season (to at least 8 March) had also been wet but the rest of April was changeable, as indeed it so often is. On 17 April Pepys, in the few notes that he left for mid-April, merely tells us 'a most pleasant evening, moonshine' but Josselin claims it is 'the hottest day I ever knew at this time of year'. On 25 April Pepys writes 'I did first put off my waste-coate, the weather being very hot, but yet lay in it at night, and shall, for a little time'. Indeed, on 30 April he reports 'I being mighty cold, this being a mighty cold day, and I had left off my waistcoat three or four days'. Josselin confirms the change on the 30th 'cold morning with ice, on the water'; we do not know the size of the pond to which Josselin referred but the date of this late frost would be 10 May in the modern calendar and such unusual frosts are damaging to fruit and vegetables (cf. Brazell, 1968, p.37).

The month of May in the Old Style sense was, however, exceptionally wet and this is clearly indicated in Pepys (1, 10, 19, 22, 23, 24, 25, 26 May) as well as Josselin. There were three days of heat (14-16 May) and Nell cut Pepys hair 'close, the weather being very hot'. The next day he put on his new suit for Church but Josselin tells us 'much rain'.

(to be concluded)

BRITISH TORNADOES AND WATERSPOUTS OF THE 1970's. PART 1: 1970.

By M. W. ROWE and G. T. MEADEN
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There were 13 known tornadoes in 1970 (nine definite and four probable), three waterspouts and four funnel clouds. From Scotland we have three reports of eddy whirlwinds. This article deals with three waterspouts and two funnel clouds which may have taken place in 1970, although the precise year of occurrence is uncertain.

FC1970March23. Exeter, Devon (SX 9193)

Mike Rowe saw a short, white funnel cloud from Exeter University at 0958 GMT. The funnel was several kilometres to the S.W.; no rotations was observed.

A low, 1002mbar, lay to the west of Brittany at 1200. South-west England had sunny periods and showers, mostly of rain, although Exeter had a shower of quite large soft hail around lunchtime.

TN1970April4. Aston, Oxfordshire (SP 3403)

Two farms at Aston were damaged by this "whirlwind", which occurred at about 2200 GMT. The corrugated iron roof of a shed 50 feet (15 metres) long was ripped off, crashing into a bungalow 100 yards away. Debris was strewn along a 200-yard trail from North Farm to the churchyard. The occupants of the bungalow noted that the curtains were sucked flat against the windows as the storm arrived; then there was hail and rain (*Oxford Mail*, 6th April). Force: probably T2.

An extremely shallow low (with no closed circulation), embedded in a northerly airstream, crossed Oxfordshire at about the time of the tornado. Most of southern England had showers during the evening.

tn1970June27/I. Whittlesey Wash, Cambridgeshire (TL 2798)

tn1970June27/II. King's Lynn, Norfolk (TF 6220)

tn1970June27/III. Wisbech, Cambridgeshire (TF 4609)

Few details are available concerning these three tornadoes. The first, reported by Michael Hunt, is probably the "whirlwind . . . near Peterborough" mentioned by L. Burch in *Weather*, 26, 273 (June 1971). Paul Richards reported that a whirlwind struck a caravan at King's Lynn; nobody was hurt. Radio news bulletins on the evening of 27th June stated that a whirlwind had overturned a caravan at

Wisbech. The three locations lie on a straight line from S.W. to N.E., although in view of the similarity of the King's Lynn and Wisbech reports there is a slight possibility that they relate to a single incident somewhere between the two towns. Further information would be much welcomed.

A cold front, associated with a low over Northern Ireland at 1200 (1007mbar), crossed England during the day. It was very warm in eastern districts, with showers and thunderstorms.

WSS1970June27. *King's Lynn, Norfolk (TF 6220)*

"Three waterspouts were observed simultaneously in the Wash near King's Lynn" (*Monthly Weather Report*, June 1970).

TN1970July8. *Duns to Preston, Borders (NT 7854-7957)*

This tornado caused a considerable amount of damage, and five people were injured. It struck a caravan site at Duns, reducing some of the caravans to matchwood and lifting tents over 20 metres into the air. An eye-witness described the tornado as resembling "a big ice cream cone". A car was lifted and damaged. Lorraine Cunningham, aged nine, who was in the car, said: "It started to move and lifted up in the air. The car was twisting round and round. I saw a caravan turning over and over and it hit the car". She had to have four stitches in a head wound. A witness said the car was lifted to a height of four feet (over one metre). After damaging the caravan site and a housing estate the tornado passed through Ashfield (NT 7955), where a Land Rover was lifted and pushed up against a house; the village of Preston was also damaged, but not as severely as Duns. Trees were blown down all the way along the track, which was about 100 metres wide; in one short stretch dozens of mature beech trees littered the road. The tornado was followed by heavy rain (*Berwickshire News*, 14th July, sent by Mr. Colin Wight. Mr. Wight noted: "I actually saw the whirlwind and experienced carpets etc. hitting the ceiling in our home"). The path length was 4km and the direction of movement was from south to north. According to *The Times* of 9th July "a year-old baby was flung the length of a caravan and out of a window" by the tornado. Force: probably T4.

This tornado occurred ahead of a cold front which was advancing slowly into Scotland from the Atlantic, reaching the Outer Hebrides by 1800 and the western Highlands by midnight. There were a few showers and thunderstorms in Scotland.

TN1970July24. *Spalding, Lincolnshire (TF 2422)*

A tornado struck Geest's Nursery at Spalding "like a high-explosive bomb", wrecking more than two acres of glasshouses under construction. Mr. J. Compton, the manager, said: "It literally ripped the structure to shreds. Three-foot-square concrete bases were tossed about and glass was flying in all directions". He added that the whirlwind then ran along the side of the existing glass and then passed across another block, causing considerable damage (*Lincolnshire Standard*, 31st July).

A low, 997mbar, was centred over Northern Ireland at 1200, with the cold front approaching Spalding at that time. Eastern areas had rain, followed by showers.

EW1970July. *Rowardennan, Loch Lomond, Central (NS 3598)*

Mr. Ian A. Clark was on a canoeing course at Rowardennan when, in the space of half an hour, "three or four waterspouts sped across the loch, one of them rushing up the beach on to the hostel lawn". Sailing dinghies and canoes were lifted and some were thrown into trees. "I recall being surprised how small the spouts were - no more than 2-3 feet diameter at eye level, and perhaps 60 feet (17 metres) high - not disappearing into the clouds as I expected". These are classic eddy whirlwinds. There was a force 6-7 westerly wind, with cumulus cloud. The year was probably 1970, but may have been 1971.

FC1970August15. *Essex*

All that is known about this funnel cloud is that it occurred at 1815 GMT. The country lay in a south-westerly airstream between a retreating high over Germany and a rapidly-deepening low which crossed Ireland during the evening. South-east England had sunny periods and a few light showers.

FC1970August20. *Kimbolton, Hereford and Worcester (SO 5361)*

No further details are available about this funnel. A low, 1001mbar, was centred over the north Midlands at 1800. The west Midlands had a sunless, cold day with rain.

WS1970August22. *Sheerness, Kent (TQ 9175)*

The *Monthly Weather Report* for August 1970 states that a waterspout was seen in the Thames estuary near Sheerness.

The low mentioned in the previous entry had moved very slowly south and filled, and was centred near the Isle of Wight, 1009mbar, at 1200 on 22nd. It was a rather cool and cloudy day in the south-east, with showers, mostly light, and brief sunny spells.

EW1970September4. *Holy Island, Arran, Strathclyde (NS 0628)*

Ms. Jenny Gibson sent TORRO a detailed description of eddy whirlwinds seen off the south-east side of Holy Island during the afternoon of 4th September. The day was very windy but sunny, with excellent visibility. The whirlwinds "were much taller than the lighthouse on the end of the island. They were obviously much more than the usual 'white horses' blown up by a strong wind . . . The spouts were slender and feathery looking; they disappeared and re-formed quite quickly, and were confined to quite a small area . . . There only seemed to be one or two at a time".

A westerly airstream covered all districts, in the rear of an occlusion which had reached the east coast of Scotland and England by 1200. It was a rather cloudy day in south-west Scotland, with light drizzle, rain or showers, mainly in the morning.

FC1970September4/10. *Abersoch, Gwynedd (SH 3128)*

Mrs. Beryl Peters saw two funnel clouds at Abersoch during the week beginning 4th September. They were over the bay (St. Tudwal's Road). They did not appear to reach the sea surface.

TN1970September9/I. *Bicker to Freiston, Lincolnshire* (TF 2237-3743)

This tornado followed a 16km track from W.S.W. across the countryside near Boston. At Bicker, where the track seemed narrow and sinuous, a tree was destroyed and others damaged. At Frampton West (TF 3040) a large glasshouse was lifted off the ground and dropped in a field of cabbages. Some of the debris was carried over 100 metres. Other glasshouses on either side of the wrecked one were almost undamaged, and nearby fruit trees, stacks of wooden crates and buildings were unscathed.

At Fishtoft (TF 3642) the "freak whirlwind" lifted the tiles off two bungalows, and one of the owners said: "It was like a bomb hitting the place". There was "a terrific swooshing sound", the windows shattered and the curtains were sucked out. A bedroom clock stopped at 0740 (0640 GMT). A greenhouse was demolished and a chicken hut carried 40 metres, leaving dead chickens in its wake. More remarkably, a Post Office van was carried 25 metres and set down neatly; the driver was not in it at the time. Brussels sprouts in a field just west of Hobhole Drain, east of Fishtoft, were uprooted in a path 8-10 metres wide. Further damage was caused in the fields between Fishtoft and Freiston. The force at Fishtoft was probably T4 (*Lincolnshire Standard*, 11th September; *Sheffield Morning Telegraph*, 10th September; letters to Michael Hunt).

An occlusion crossed the area at about the time of the tornado, associated with a very deep low (for the time of year) which was off N.W. Ireland, 958mbar, at 0600. Eastern areas had rain, heavy at times, during the early morning, followed by showers.

TN1970September9/II. *Boston, Lincolnshire* (TF 3343)

Three houses in Jubilee Avenue were struck by a tornado at about 0630 GMT. The chief damage was the removal of slates, suggesting a force of T2. Mr. Richard Roberts said: "I thought it was a sonic boom or something". Another witness, 15-year-old Charlie Baxter, described the tornado as "like a grey whirlwind, just like you'd see on the films. It was about the size of a house and moving really fast, kicking up stones and dirt as it went" (*Lincolnshire Standard*, 11th September).

TN1970September10. *White Stake to Walton-le-Dale, Lancashire* (SD 5225-5527)

Strong winds caused damage at several places between Leyland and Preston, and some of it was due to a tornado. At White Stake the tornado tore the roof from a house (suggesting a force of T4); windows were broken by flying debris and chicken cabins smashed to pieces. Mrs. Anne Haselden was picked up and carried 30 metres; she escaped with slight bruising. At least eight trees were blown down. At Penwortham (probably Penwortham Lane, SD 5326) "sheds, garages and greenhouses were whipped into the air and smashed to pieces". Tiles were torn off and fruit trees uprooted. At Walton-le-Dale a warehouse was damaged when the roof was lifted and partly caved in. A 20 by 15 foot (6 by 4m) door was blown across the River Darwen; 20 trees were blown down (*Lancashire Evening Post*, 10th September; *Bolton Evening News*, 10th September; several other newspapers).

The deep low of the previous day was off northern Scotland, 974mbar, at 1200 on 10th. It was a windy, showery day in north-west England, with little sunshine.

WS(-TN?)1970September15. *Aberystwyth, Dyfed* (SN 5881)

A waterspout was seen over the sea near Aberystwyth (*Monthly Weather Report*). It was also reported by Mrs. Beth Howell, who added that a whirlwind was said to have overturned caravans at Clarach Bay (SN 5883). It is therefore possible that the waterspout came ashore as a tornado.

Britain was within the circulation of a shallow low, with an ill-defined centre over East Anglia, 1006mbar, at 1200. Later in the day a north-westerly flow spread to most areas. The nearest *Daily Weather Report* station to Aberystwyth, Aberporth, reported occasional rain and showers (at least one accompanied by slight hail).

TN1970October19. *Enderby, Leicestershire* (SP 5399)

This T2 tornado struck at about 0430 GMT, ripping off tiles, dislodging a chimney and shattering greenhouses and sheds. Windows were broken by flying debris. The noise of the tornado was variously described as "a terrific whirring sound", "a terrific roar . . . as if an aircraft was in trouble" and "like a dozen express trains". Just before the tornado struck, Mrs. Alice Hall saw "a purple flash like lightning" (*Leicester Mercury*, 19th October; *Leicester Advertiser*, 23rd October).

A deep low moved east during the night of 18-19th and at 0600 was near Trondheim, Norway, 959mbar. The cold front reached the Scottish border at midnight and at 0600 lay from London to Cornwall. It probably passed through Enderby at about 0300, so the tornado was rather behind the front if the reported time is correct. Midlands stations reported rain on the front, followed by colder weather and light showers.

q1970November3. *Newport, Gwent* (ST 3187)

High winds ripped slates and TV aerials from roofs, and a plate glass window in a hairdresser's shop was smashed. The manageress of the shop said: "It was like a whirlwind. The wind got right through and also broke a window at the back of the shop". More evidence is needed before this can be classified as a tornado.

A rather intense low moved across Scotland, reaching the central North Sea, 982mbar, by 1800, with a strong west to north-west airstream over England and Wales. Rhooose (Cardiff) reported sunny periods and light showers.

TN1970November29. *New Barnet, Greater London* (TQ 2696)

A T2 tornado caused structural damage (mainly the removal of slates) along a track 400 metres long and 50 metres wide. The tornado occurred during a thunderstorm which had begun at 1555 GMT (C. G. Holmes, *Weather*, 26, 180, April 1971). Mrs. Susan Ward has written to TORRO describing what is probably the same tornado. She observed the funnel: "I suddenly saw a waterspout swirling and bending at quite a speed".

A low moved from the Bristol Channel, 990mbar, at 1200 to near London, 988mbar, by 1800. The tornado occurred in the airstream behind the fronts. It was a sunless day almost everywhere in south-east England; but very mild, with frequent rain, heavy at times; no *Daily Weather Report* station reported thunder.

EW1970November. *Finart, Loch Long, Strathclyde (NS 1988)*

Mrs. Muriel McLeod saw a whirlwind on Loch Long, slightly north of Finart. It crossed the loch and disappeared.

TN-WS1970December6/I. *Littlestone-on-Sea, Kent (TR 0824)*

"A whirlwind crossed the Kent coast near Littlestone yesterday and headed out to sea, causing a waterspout 40 feet high. No damage was reported" (*Daily Telegraph*, 7th December).

This tornado and the next were most probably on a cold front which moved south-eastwards, reaching Littlestone about 1200 and Gosport probably about 1000. There was a low, 991mbar, centred between the Faeroes and Norway at 1200. In south-east England the passage of the front brought rain, followed by showers, some of which were accompanied by hail.

tn1970December6/II. *Gosport, Hampshire (SZ 6199)*

The *Monthly Weather Report* for December 1970 mentions that a whirlwind was seen at Gosport. No further details have come to light.

The precise date of the following events is not known:

FC1970?summer. *Ipswich, Suffolk (TM 1744)*

WS1970?summer. *Felixstowe, Suffolk (TM 3034)*

These two sightings were reported in a letter to TORRO. In the first incident "a grey funnel of cloud" appeared over Ipswich. It remained almost stationary and lasted about 15 minutes. The waterspout appeared as a "column of water" off Felixstowe; it lasted for 10-15 minutes. The weather on both occasions was cloudy and windy.

WSc1970August. *Severn Bridge, Avon/Gloucestershire (ST 5690)*

Ms. Lorna Reed was crossing the Severn Bridge in August, about 1970, when she saw a waterspout rising from the water on the north side of the bridge. The spout was funnel-shaped and could be seen to be rotating. There was torrential rain at the time.

FCc1970. *Glasgow area?*

Around 1970 Mr. A. W. Smith, of Glasgow, saw a black column coming from the clouds; he did not give the location of his sighting. On the same day, there was serious flooding at Kilmarnock. TORRO would be very grateful if any Scottish reader could pinpoint the date of this flood.

WWc1970. *Fencott, Islip, Oxfordshire (SP 5716)*

A whirlwind (locally known as a whirly puff) uprooted a large bush, damaged a haystack and took leaves off a hedge (information from Mr. A. F. Goddard). It is possible that this was a severe land devil rather than a tornado.

WSc1970/4June/July? *Off Penarth, South Glamorgan (ST 2271)*

Mr. Jon Iliffe was sailing about 2-3 miles (3-5km) east of Penarth when he spotted a waterspout. The time was about 14 GMT. The weather was sunny, with squally showers at times. Two boys who were sheltering from a shower were killed by lightning.

The International TORRO Tornado Intensity Scale

T0	LIGHT TORNADO 17-24 m/sec., 39-54 mph	Loose light litter raised from ground-level in spirals. Tents, marquees seriously disturbed; most exposed tiles, slates on roofs dislodged. Twigs snapped; trail visible through crops.
T1	MILD TORNADO 25-32 m/sec., 55-72 mph	Deckchairs, small plants, heavy litter made airborne; minor damage to sheds. More serious dislodging of tiles, slates, chimney pots. Wooden fences flattened. Slight damage to hedges and trees.
T2	MODERATE TORNADO 33-41 m/sec., 73-92 mph	Heavy mobile homes displaced, light caravans blown over, garden sheds destroyed, garage roofs torn away, much damage to tiled roofs and chimney stacks. General damage to trees, some big branches twisted or snapped off, small trees uprooted.
T3	STRONG TORNADO 42-51 m/sec., 93-114 mph	Mobile homes overturned/badly damaged; light caravans destroyed; garages, outbuildings destroyed; house roof timbers considerably exposed. Some of the bigger trees snapped or uprooted.
T4	SEVERE TORNADO 52-61 m/sec., 115-136 mph	Mobile homes destroyed; some sheds airborne for considerable distances; entire roofs removed from some houses or prefabricated buildings; roof timbers of stronger brick or stone houses completely exposed; possible collapse of gable ends. Numerous trees uprooted or snapped.
T5	INTENSE TORNADO 62-72 m/sec., 137-160 mph	Motor cars levitated; more serious building damage than for T4, yet housewalls usually remaining; the weakest, old buildings may collapse completely.
T6	MODERATELY-DEVASTATING TORNADO 73-83 m/sec., 161-186 mph	Heavy motor vehicles levitated; strong houses lose entire roofs and perhaps also a wall; more of the less-strong buildings collapse.
T7	STRONGLY-DEVASTATING TORNADO 84-95 m/sec., 187-212 mph	Frame house completely demolished; some walls of stone or brick houses beaten down or collapse; steel-framed warehouse-type buildings may buckle slightly. Locomotives thrown over. Noticeable de-barking of any standing trees by flying debris.
T8	SEVERELY-DEVASTATING TORNADO 96-107 m/sec., 213-240 mph	Frame houses and their contents dispersed over big distances; most other stone or brick houses irreparably damaged; steel-framed buildings buckled; motor cars hurled great distances.
T9	INTENSELY-DEVASTATING TORNADO 108-120 m/sec., 241-269 mph	Many steel-framed buildings badly damaged; locomotives or trains hurled some distances. Complete debarking of any standing tree-trunks.
T10	SUPER TORNADO 121-134 m/sec. or more, 270-299 mph or more	Entire frame houses and similar buildings lifted bodily from foundations and carried some distances. Steel-reinforced concrete buildings may be severely damaged.

For further information refer to *J. Meteorology*, vol.1, no.8, 242-251 and vol.8, no.79, 151-153.

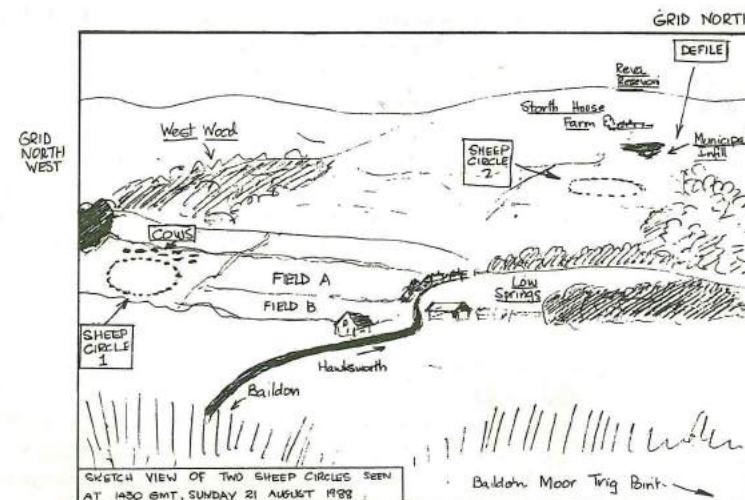
SHEEP IN CIRCULAR FLOCKS IS THERE A METEOROLOGICAL, OR SOME OTHER, CONNECTION?

On 21 August 1988 Mr J. C. Belcher witnessed a curiosity of co-ordinated animal behaviour which was of quite unexpected character for the animal kingdom, and reported it to me because of my well-known interest in circle phenomena. The incident concerned sheep, that innocent and docile beast who is forever content to graze and turn and step at random, subject only to retaining the protective solace of the remainder of the flock. Sheep simply do not organize themselves into parade-ground alignments, or as Mr Belcher put it in a letter:

"By their very nature sheep tend to be stubborn self-willed animals exhibiting individual characteristics not suggestive of good group co-ordination. For example, when disturbed by a potential predator, a flock of sheep tends to mass protectively in a group of irregular outline, the group being formed of individual groups of small numbers of sheep. When grazing undisturbed, sheep tend to fan out from a given point, sometimes following a dominant group leader. Progress is usually unco-ordinated and ragged. In general, patterns presented by sheep *en masse* are seen to be haphazard, indeed generally random in nature. It follows that any suggestion of flocks of sheep forming geometric patterns would appear to be highly improbable, since this would call for group co-ordination only to be found in such as wolves and wild-dogs. In view of this it would appear that certain exceptional observations made on Sunday 21 August 1988 would be worthy of recording".

Out on an afternoon drive Mr Belcher parked his car near the trigonometric survey point on Baildon Moor, near Leeds, in Yorkshire, at approximately 1430 GMT facing north-east (Figure 1). His wife suddenly exclaimed: "Look at that circle of sheep in that field!" That was Sheep Circle 1 on the plan where "a hundred or so sheep were in a circular formation, each sheep being more or less equidistant from the next. At the north end of the field some 20 or 30 cows were standing, grazing and chewing cud in the usual haphazard manner. The circular formation of these sheep was so unusual that I thought I was looking at bales of hay set out in the field by the farmer. Indeed, a stone-age stone circle might have been appropriate on this occasion. I looked around from north-west to north-east, and then espied a similar sheep circle (2) on a plateau opposite . . . In the sector between north and north-east, flocks of sheep were in other fields but in no case exhibited the circular formation, being in typically haphazard groups". In a second letter Mr Belcher emphasized that the sheep of the two circles were "variously standing, laying down, or grazing. All quietly occupied, but nevertheless forming this very regular circular formation".

Mr Belcher suggested that perhaps some mysterious radiation was emanating from below or above the immediate vicinity, as a result of which some central circle of influence prevented the sheep from moving inwards while yet constraining them to a sort of outer annular ring of influence (while noting also that there was no electric fence!). Nonetheless, instead of hypothesizing extraordinary and peculiar forces of unknown origin, why not, as always in science, first check to see what sort of known forces might have been operating.



WEATHER CONDITIONS: Wind light to moderate from WNW, sunny intervals with white squally showers.
[For details see Ordnance Survey 1:50,000 Series, Sheet 104.]

Perhaps our readers have some ideas. (Do write). At any rate I commence with a prosaic proposal by simply suggesting that inoffensive whirlwinds may have played some role. For suppose that the sheep were initially fairly close to one another but distributed at random within the group, then following the start-up of some minor whirlwind in their midst the disturbed sheep drifted apart just by easing themselves placidly beyond the reach of the mischievous wind till the wind-speed, being low enough, they felt able to settle again and graze in peace. If this is so, then the event had not long happened when Mr and Mrs Belcher noticed the sheep circles.

G. T. MEADEN

AN AGRICULTURAL COLLEGE'S USE OF A AUTOMATIC WEATHER STATION

For the first time ever, the Meteorological Office is accepting monthly weather reports in a computerised form using data generated by an automatic weather station. The weather station was manufactured by the Didcot Instrument Company, and is at a long established Met. Office monitoring site - the Harper Adams Agricultural College in Shropshire.

British weather is among the most complex of any country, and can change extremely rapidly. The Met. Office is recognised as a world authority in monitoring and unravelling these complex atmospheric conditions, and offers information via a variety of channels, from broadcasts on radio and TV to more specialised services specially tailored to particular industries. One such industry is

agriculture, and the Met. Office works closely with the Agricultural Development and Advisory Service (ADAS) as well as other major agricultural bodies to provide pertinent advice. Reports can be obtained on an hourly, daily or longer-term basis, and are geared specifically to the needs of livestock and arable farmers and growers.

The Met. Office relies on weather data from a number of sources, not only data from its own weather stations but also from a number of registered outposts scattered throughout the British Isles, one of which is Harper Adams. But of course, for meaningful collation, the data must be produced in a standard manner. Consequently strict guidelines are published on acceptable weather monitoring instrumentation, and forms are issued which must be completed in a prescribed way.

Harper Adams Agricultural College, situated on the Shropshire Plain in the centre of an intensive and progressive mixed farming area, has been monitoring weather for the Met. Office for over 60 years. The arrangement is mutually beneficial: the Met. Office extends its long-term records with information from a good base in the West Midlands; Harper Adams finds the detailed weather data useful in both research and in student work. The College currently offers a choice of eleven degree, diploma and post-graduate courses in diverse aspects of agriculture.

Until recently, weather monitoring has involved somebody recording a number of parameters every single morning at 09.00 GMT, from equipment housed in the College's grounds. These observations (including wind direction and speed, maximum and minimum air temperatures, grass minimum temperature, actual air temperature, 10cm and 20cm soil temperatures, wet and dry bulb temperatures (from which % relative humidity is calculated), rainfall, sunshine hours and solar radiation) would then be entered, by hand, on the standard form. At the end of each month, the information would be totalled, averaged, summarised, and submitted.

The new Didcot weather monitoring system, which has automated this procedure, has been erected alongside the manual equipment which it will supercede. It consists of a Met. Office regulation-sized 5 metre mast, constructed of anodised aluminium and rigidly held in place by four guys. To this are attached a number of instruments, used for sensing the various weather parameters. In addition to the requirements of the Met. Office, the weather station provides essential information for use with college projects. The programmable nature of the station's data logger allows complex analysis of data and calculation of complex formulae, such as the PENMAN equation for potential evaporation calculation.

At the top of the mast are a 3-cup anemometer (which can have an optional reed switch or tachogenerator) and an accurate wind direction sensor with inbuilt potentiometer. Both are constructed from anodised aluminium and stainless steel. Half-way down the mast is a crossarm bearing a thermal radiation screen. This comprises a 23cm diameter stainless steel reservoir with mountings for two platinum resistance thermometers. In place it acts as both a Stevenson screen and a large wet bulb reservoir; its 1 litre capacity is sufficient for unattended operation for up to a month. In addition, and of particular interest to Harper Adams, it also incorporates a fan. At low wind speeds, this is used to aspirate the screen, giving



Fig.1: The Didcot Automatic Weather Station at the Harper Adams Agricultural College.

accurate RH readings even under the driest of conditions. Also on the mast are a leaf wetness indicator and a net radiometer. Located at the opposite end of the crossarm to the radiation screen, the net radiometer monitors the earth/sky radiation balance.

Other sensors required for Met. Office purposes, but not on the mast itself, are a grass minimum temperature thermometer, three soil thermometers (buried at regulation depths of 10cm, 20cm and 1 metre), a Kipps solarimeter to measure direct solar radiation, and a Didcot tipping-bucket rain gauge. The latter is of especial interest because it can be heated. Not only does this mean that it will switch on and melt snow in winter, but it is more automatic than the plastic ones of other suppliers which do not offer a similar heating facility. Without the heating facility, someone must melt any snow in order to take the 09.00 GMT reading.

In use, data are collected at intervals by the various sensors and stored in a data logger sited below the mast's crossarm. Once a week, this information is downloaded to a portable Toshiba T1100+ computer, and, at the moment, is transferred to an Apricot XENI/386 IBM-compatible PC. However, eventually, according to Ray Smith, Head of the Crop Science Department, the College hopes to get a direct telephone link to the weather station to undertake this stage without any operator intervention. Data from the weather station enter a spreadsheet program which closely mimics a Met. Office form. The program, written by Mr Andy H. Warner, Computing Technician, is a macro program on Supercalc 4,

which inserts the input data into rows and columns, and performs all necessary computations. The spreadsheet is printed on an Epson printer, and submitted to the Met. Office. It is hoped, however, to get another direct telephone link here (with the Met. Office) so that this stage too can become automatic.

Ray Smith's decision to opt for Didcot instrumentation was due to the high quality of the instruments, based on his experiences with an initial purchase of a neutron probe. With the automatic weather station, he was particularly impressed with the heatable rain gauge and its relative-humidity monitor. The traditional wet and dry thermometers have excellent long term stability, high accuracy and are easy to calibrate, compared with solid-state RH sensors. The aspirated screen enhances the accuracy in still and humidity conditions. This is especially important to Harper Adams because high humidity (more than 90%) is required for studying some crop diseases – e.g. potato blight.

Mr Smith took delivery of the weather station at the end of March, spent April erecting it, and ran it in tandem with the manual station during May and June. After an inspection by a Met. Office representative, the automatic system came into full operational service in July and has been running extremely well ever since.

Having an automatic weather monitoring system confers a number of advantages. It saves considerable time at the end of the month not having to do the monthly summary by hand; readings need only be taken at weekly intervals, and there is no more necessity for daily recording. The improved weather monitoring facility should be invaluable to Harper Adams. Not only has the College now got an automated and more accurate way of logging climatic conditions, but also a new means of building on its existing impressive records. This detailed information will be used in crops research and student projects, for example, in disease studies; to calculate accumulated temperatures; or in comparing several growing seasons.

Further information can be obtained from the Didcot Instrument Co Ltd, Station Road, Abingdon, OX14 3LD, (telephone Abingdon 22345).

WORLD WEATHER DISASTERS: JULY 1988

1-31: Heat and drought continued in many areas of the U.S.A., forest fires reported, on the 7th, a 4,000 hectare fire burned near to Mt. Rushmore in South Dakota, the pall of smoke visible 258km away; up to 25mm of rain fell on the Midwest on the 10th, helping to relieve drought. Thunderstorms on the 19th caused flooding in New York City, where one person died when they were hit by bricks dislodged from a building by lightning, up to 75mm of rain fell, storms also reported from the Midwest, also on the 19th and the 20th, up to 100mm reported in the Ohio Valley.

On the 25th major forest fires reported in states of Montana, Utah, Colorado, Idaho and Wyoming, four serious fires in the Yellowstone National Park, Wyoming, fires also reported from states of Alaska, Arizona, Oregon and Washington by the 27th. It was reported on the 30th that the fire near Mt. Rushmore had burned seven homes, 14 outbuildings, four cars and a bridge on

outskirts of Rapid City. *Daily Telegraph*, *International Herald Tribune*.

1-23: Monsoon rains and widespread floods in India, on the 15th floods in Surat, Gujarat state left 15 dead and forced the evacuation of 25,000 others, the following day, the 16th, 12 further deaths reported from states of Gujarat, Uttar Pradesh and Kashmir and the city of Bombay. By the 23rd 250 deaths reported since the 1st by floods and landslides in northern India, states of Punjab, Haryana and Himachal Pradesh, a further 120 deaths reported from water-borne diseases. Two million people affected by the floods in northern, eastern and western India. *Lloyds List*.

1: Gale force winds and heavy rains in and around Milano, Italy, left two dead and dozens injured. Hundreds of trees and power lines brought down throughout the city during the hour-long downpour, homes, shops and offices flooded. In the countryside, high winds ripped roofs off houses and hailstones and rain severely damaged crops. *L.L.*

3-11: Heatwave in many areas of southern Europe, brief details below:-

Greece: Temperatures up to 48.8°C reported from Athens, and 56 deaths reported throughout Greece from the heat, forest fires from the 8th to the 10th on islands of Corfu and Cephalonia left at least seven dead.

Italy: Temperatures of up to 40°C reported on the 6th, one death reported from Bari.

Turkey: High temperatures reported.

Yugoslavia: Temperatures of over 40°C reported, at least 26 deaths reported from Beograd, in Macedonia republic water rationing introduced because of heat and drought. *I.H.T.*, *D.T.*, *L.L.*

3-20: Torrential monsoon rains in Bangladesh, widespread flooding reported from many areas of country, at least 155 deaths reported in floods and landslides and six million people affected by the floods in 10 of Bangladesh's 64 districts, other deaths reported from water-borne diseases. *L.L.*, *I.H.T.*, *Birmingham Evening Mail*.

3-31: Many parts of China affected by floods, drought and hailstorms, brief details below:-

3rd-31st: Severe drought and heat in many areas of China, in southern provinces a heatwave with temperatures of up to 40°C left 1440 people dead from heatstroke, heart disease or fever, 930 died in city of Hangzhou, Zhejiang province, the drought has struck 10 provinces in southern and central China as well as the northern provinces of Hebei, Shanxi, and Shaanxi. Zhuxi county in Hubei province suffering its worst prolonged drought for 111 years, 23 counties in province affected by drought and 20 rivers reduced to 'mere pools', more than 100 rivers north of the river Huaihe in eastern Anhui province have dried up because of the heat, more than 27 million acres of crops in southern provinces either destroyed or damaged by the heat, it was reported on the 28th that heavy rains had partly relieved the drought in southern areas of the country.

10th: Heavy rains touched off mudslide which hit power station in the Liangshan Yi autonomous region of Sichuan province leaving 35 dead, 10 injured and one missing.

- 20th: It was reported on this day that flash floods and mudslides killed at least 15 people and stranded about 1000 climbers on Mt. Huashan, central China.
- 23rd: Heavy hailstorm, accompanied by rain, hit Qingyang county, Gansu province, in north-west of country, leaving at least 54 people dead, over 137mm of rain fell in area, destroying 730 homes and mountain cave dwellings.
- 29th-30th: Torrential rains in Zhejiang province left 264 people dead and 50 others reported missing, the rains were described as the worst in 100 years, up to 610mm of rain fell in eight hours in the worst affected areas, floods described as worst in 40 years, damage put at \$215 million to crops, buildings and bridges, 16949 homes, 100 reservoirs and 305 bridges destroyed.
- 30th reported: A flash flood sank more than 100 vessels in a canal in Shandong province, undetermined number of casualties. *L.L., D.T.*
- 4: Thunderstorm at Aylesford, Kent, lightning started fire at the Quarry Wood industrial estate causing damage estimated at £6 million. *D.T.*
- 4: M. Bulk carrier 'Singa Sea' broke up in storm off west coast of Australia, one crewman died, another 18 were missing. *L.L.*
- 5: Gales and torrential rains in two Australian states, winds gusted to 160km/h in Sydney, New South Wales, roads and houses flooded, people evacuated, five deaths reported, three in Sydney in road traffic accidents. *B.E.M.*
- 7: Heavy thunderstorm in Brownsville, Texas, U.S.A., between 62mm and 75mm of rain fell in a half hour period at about 1430 hours a department store collapsed due to weight of water on roof leaving 14 dead and at least 41 injured. *L.L.*
- 8-18: Torrential rains, floods and landslides in Alagoas state, north-eastern Brazil, left 54 dead and 35,000 homeless, lagoons surrounding capital of Alagoas state are 3.05 metres above normal. *L.L., B.E.M.*
- 8-20: Rains, floods and landslides in South Korea, three days of rains and mudslides beginning on the 13th left 16 dead and two others missing, four of dead in mudslides and 12 in floods, all in south of country where more than 250mm of rain fell, on the 20th further rain and mudslides left 16 dead and nine others missing, six died in a mudslide at Yongwol 137km south-east of Seoul, over 250mm of rain fell on city during day. Up to 201mm of rain fell in other areas, 650 homes flooded, 2640 people evacuated. Since rainy season began on the 8th, 32 deaths reported, with another 10 missing. *L.L.*
- 8(reported): Heavy rains in Portugal have caused 'millions' of £'s damage to crops. *D.T.*
- 10: Floods in parts of Texas, U.S.A., left five dead, all in station wagon washed away by a flooded river. *B.E.M.*
- 13-20: Monsoon rains in Pakistan, from 13th to 17th widespread torrential rains reported from all four provinces of country, 11 deaths reported from Punjab and Frontier provinces due to electrocution. On the 17th 3mm of rain fell in Karachi, on the 19th a further 28mm fell on city, leaving at least eight dead in city, roads flooded. *L.L.*
- 14-18: Timber and brush fire on Las Palmas, Canary Isles, 6000 hectares of pine trees and scrubland and damaged another 15000 hectares, the fire burned on a 40km wide front and devastated 10% of the island. *L.L.*

- 15: Two months of rainfall fell in three hours in north west Azerbaijan S.S.R., hundreds of homes washed away. *D.T.*
- 15-16: Tornadoes, wind and hail affected portions of Nebraska, Iowa and Kansas. One of the tornadoes hit Council Bluffs, 160 homes severely damaged and thousands of trees uprooted. A thunderstorm with winds up to 148km/h and four funnel clouds moved over Omaha, Nebraska, at least 64 people injured in storms, insured losses put at \$27 million in Iowa, \$9 million in Nebraska and \$1 million in Kansas. *L.L.*
- 17: Storm hit outer north-eastern suburbs of Perth, Western Australia, worst hit area was Midvale, where about 40 buildings were severely damaged, trees uprooted and power lines brought down, no casualties reported. *L.L.*
- 17-22: Forest fires in southern Yugoslavia, some 1000 hectares of oak forest burned in Macedonia, four injuries reported. *L.L.*
- 18-20: Typhoon "Warren" hit the Philippines and southern China, details below:-
- Philippines:* hit on the 18th with winds of 185km/h in Cagayan province, hundreds of families made homeless, 28,750 acres of ricelands and 70,500 acres of corn damaged, one death reported.
- China:* hit Guangdong province on the 19th with winds of 129km/h and torrential rains, 4539 homes destroyed, nearly one million acres of farmland flooded, 17 deaths reported, at least six of which died in city of Shantou, more than 4 million people affected by storm. *L.L.*
- 19-20: Storms and floods in the Basque region of northern Spain left at least 14 dead, most of dead in motor cars swept away by floods. Seven provinces affected by storms, province of Guipuzcoa worst affected, in Zaragoza province a 15 minute wind and hailstorm destroyed cereal and fruit crops to a value of \$8.2 million. Vines in many parts of the Rioja district damaged by hail. *L.L., D.T., B.E.M.*
- 20: River burst its banks flooding village in Hong Kong, at least 19 people rescued by helicopters. *B.E.M.*
- 21-22: Thunderstorms in many areas of Great Britain, roads in Redruth and Camborne, Cornwall, flooded, police station at Perranporth hit by lightning. In Birmingham 16 homes flooded in the Perry Barr district of city when river Tame burst its banks after up to 25mm of rain fell on Birmingham and the Black Country. *B.E.M., D.T.*
- 23: Lightning struck village in the Swat region of Pakistan, leaving 36 dead. *D.T.*
- 23: Gale hit town of Singkawang, west Kalimantan, Indonesia, damaging 'tens' of houses and uprooting 'dozens' of trees, the storm which lasted 20 minutes, also capsized launch off the coast leaving five people feared dead. *Jakarta Post.*
- 23-25: Floods in Palmerston North, North Island, New Zealand, nearly 1000 people evacuated from their homes. *L.L.*
- 23-25: Thunderstorms in many areas of Europe, brief details below:-
- 23rd: Thunderstorm in Paris, France, and surrounding suburbs, many trees uprooted in the Seine-et-Marne district, east of Paris. The storm was accompanied by egg size hailstones, the skylight of a shopping mall in Torcy, an eastern suburb of Paris, shattered by the hailstones, 16 people injured, one motorist died when uprooted tree hit car.

- 24th: Storms in eastern Holland injured two children.
- 24th: Hailstorms and hurricane force winds in Bavaria, West Germany, seven people injured by falling trees and roof tiles, nine others injured in traffic accidents, damage estimated at several million marks. Damage in neighbouring state of Baden-Wurtemberg put at at least two million marks, lightning set fire to three farmhouses and several barns.
- 25th: High winds and hailstorms hit Czechoslovakia, damaging crops, roads, buildings and electricity supplies. Winds gusted to 150km/h across most of country. Hailstones in central Bohemia damaged wheat, maize and barley crops, while rail services in eastern Bohemia were disrupted by uprooted trees. L.L., B.E.M.
- 25-26: Gale-force winds and storms caused an estimated A\$1 million in Melbourne. Areas worst affected were Cockatoo and Selby outer Melbourne. L.L.
- 28: Sudden storm in the Gulf of Riga, Latvian S.S.R. scattered 31 vessels competing in yacht race, five vessels washed ashore near Riga, one yacht sank, leaving one dead, three others missing. L.L.
- 28(reported): Floods in Afghanistan in June 1988, left 161,000 people homeless and caused damage estimated at \$260 million. L.L.

ALBERT J. THOMAS

LITERATURE REVIEWS AND LISTINGS

Book Review

AN INTRODUCTION TO BOUNDARY LAYER METEOROLOGY.
By Roland B. Stull. Kluwer Academic Publishers, Dordrecht, Boston & London 1988. 666pp. £64 in UK, US\$99 (Paperback available).

This large and ambitious work may aptly be retitled "Roland Stull's Boundary Layer Meteorology" because it contains some interesting new ideas which are contentious and not yet internationally accepted. The work has a distinctly American flavour to it.

To begin with, there is Stull's definition of the Boundary Layer (BL) as "that part of the troposphere that is directly influenced by the presence of the earth's surface, and responds to surface forcings with a *timescale of about an hour or less*" (p2). Surely, this is bound to encompass some 'General Meteorology' and is one reason why the book under review is so long? For example, with "active" cumulus formation (p563), while cumulus mediocris comes within the scope of BL Meteorology, cumulus congestis and cumulonimbus (quite capable of forming within half an hour) apparently are not! Therefore, in studies of convective situations, why does BL meteorology not stop with the condensation level (this would not necessarily exclude such research as cumulus onset time, mentioned on p564) and leave the convective cloud dynamics to other researchers? As it is, Stull even mentions thunderstorms, whose "interaction with the BL will be reviewed in this book" (p3).

Approximately 200 pages are devoted to turbulence; its flux, variance, kinetic energy, and closure. This appears to be the author's main research interest, since a back-jacket introductory note mentions the excitement of "the challenge associated with turbulent flow – one of the unsolved problems in classical physics". This whole adventure into turbulence could be interpreted as having much more to do with interaction between BL and free atmosphere than with surface forcings if one follows Brunt's 1939 definition . . . "The transport of heat and water vapour (within the BL) is brought about entirely by molecular diffusion while outside it, in the turbulent region, the transfer is brought about by eddies" (see "Physical and Dynamical Meteorology", p259).

No doubt, Brunt would be considered very 'old hat' by this author who also has some harsh things to say about the 'Ekman spiral' on the basis that the idea "has been around for a long time" (p214) . . . "Observed stable BL's can have supergeostrophic winds at low altitudes, making the Ekman solution even qualitatively incorrect". However, corroborative evidence of this statement is not offered where it could have been; e.g., by mentioning case studies using wind 'profilers' (developed at NCAR, Boulder, Colorado) in the 'Measurement and Simulation' section, which otherwise gives a good introduction to use of Radars, Sodars, and Lidars. However, the suggestion (on p414) that instruments be exposed in a Stevenson Screen at "a height of about 2m above the local ground level" is 'on a par' with the statement defining 'fog' as "a *stratocumulus* cloud that touches the ground" (p3).

To the synoptic meteorologist, there is only one treatment of a weather 'front', for which we have to wait until p593, and that is connected with the sea breeze. Work on land breeze fronts has not been incorporated, and a lot more could have been made of the final chapter on 'Geographical effects' which have been largely divorced from the theoretical mathematics making up the main body of this work. Perhaps a more creative approach would have been to link the two more closely, since BL work is by definition, directly associated with the effects of the earth's surface.

There are no photographs or satellite pictures to illustrate the theory, and this may be regarded very much as a book for (a) specialist research (b) those particularly interested in low-level turbulence. For the price, most people would prefer to borrow from a good library than to buy – the book remains cheaper in the USA than in the UK while exchange rate remains above \$1.55 = £1. Kluwer should take note that this is seen as a continuing policy on their part which is unfair to the less-well-endowed European reader.

W. S. PIKE

Book Listing

WEATHER IN FOCUS. By Melanie Quinn. Hobsons Publishing PLC, Bateman Street, Cambridge CB2 1LZ 1988, 32pp., £1.95.

This is the third publication from Hobson's *In Focus* series (the others deal with flight and biotechnology). It has been produced in conjunction with and sponsored by the Meteorological Office and is designed "for students aged 14 to 16 studying GCSE Geography, Science and Environmental Science". There are numerous illustrations (photographs, maps and diagrams), mostly in colour, together with

short commentaries on each of the subjects mentioned. Ideas are given for "practical activities and further research" and there is a separate 8-page booklet of notes for teachers.

L. T.

LETTERS TO THE EDITOR

SEVERE SMOG PROBLEMS IN DUBLIN

A good glowing coal-fire is a cosy, homely facet of Irish life. Unfortunately in the Irish capital the resultant sulphur-filled smoke from thousands of chimneys across the city on calm cold winters evenings and nights brings its problems in the form of smoke-haze known as smog.

The situation is worst when anticyclonic conditions cover Ireland and surface winds fall slack as the sun goes down. Stagnant air conditions develop, and rising warm air over the Dublin urban block augments the temperature inversion on the northern side of the Wicklow Mountains. The inversion conditions ensure that smoke from domestic coal, as well as car exhaust fumes and smoke from industrial sources, remain practically motionless in the Dublin area, and worsen as long the temperature inversion lasts.

Severe smog occurrences developed on several occasions this November during anticyclonic interludes, and smog levels exceeded permitted E.E.C. safety limits by a factor of four or five. Such occurrences are very dangerous for the elderly and those suffering cardio-bronchial problems. In the past, because doctors associated with Dublin's hospitals claimed that admissions for such health-related problems increase dramatically when severe smog starts, the Irish Meteorological Service have undertaken to issue warnings when smog conditions are expected. Doctors then warn the people at risk to remain indoors until smoke levels return to normal. The Irish Government have held discussions on measures to alleviate the present difficulties, and a drive to encourage the burning of smokeless fuels has been initiated. Smokeless zoning begins shortly in certain parts of the city such as Ballyfermot and Neilstown. Price reductions in the cost of smokeless fuels are promised too, for smokeless fuels are currently dearer than smoke-producing fuels - which is why many householders are reluctant to change over.

It is agreed that Dublin has a very serious problem and that it is high time measures were taken to bring the city into line with other major European cities who have had rigorous smoke-control measures for many years now.

Mount Russell, Ardpatrick, Kilmallock, County Limerick, Ireland.

DAVID MESKILL

A MID-WINTER BUTTERFLY

My combined hobby of watching nature and weather together never ceases to spring surprises. At noon on 28 December 1988 a Small Tortoiseshell butterfly alighted on the south-facing white-sandtexted wall of my bungalow and remained sunning itself for a short while. I think that this is the nearest to the winter solstice that I have seen a butterfly in flight. Screen temperatures that day were not as high as on 26th when I did not notice any activity (12.9°C at 1245, maximum 13.4°C on 28th; 13.8°C and 14.7°C on 26th), but there was less cloud cover and the black-bulb in vacuo readings were up (at 24.0 and 18.5°C respectively), and the breeze was lighter (S.W. force 2, against S.W. force 4). The last date of sighting of the Small Tortoiseshell given in my recent article on the butterflies of 1988 (*J. Meteorology*, vol.14, no 135, pp.18-21) requires amendment.

13 Stowey Park, Yatton, Bristol.

A. H. WEEKS

THE 'BEST' DECEMBER OF THE CENTURY AT DOVER?

According to media reports I have heard and read December 1988 was Britain's mildest December for forty years. Here, at Dover, as the following table shows, one has to go back to 1934 to find a milder December. 1934 was the mildest of the century in these parts, followed by 1918, and 1988 comes third.

	Mean Max	Mean Min	Rainfall
December 1918	10.4°C	5.6°C	68.6mm
December 1934	10.9	7.8	139.2
December 1988	10.2	4.9	21.2

If all three factors (mean maximum, mean minimum, rainfall) are combined, December 1988 could be regarded as the 'best' December of the century at Dover, there also being an absence of snow, hail, thunder, cold days (the lowest maximum was 5.6°C), and winds from N. through E. to S.S.E.

Manston had 51.2 hours sunshine this December. At Dover in December 1934 there were 21.4 hours and in 1918 34.4 hours.

River, Dover, Kent.

F. G. THOMAS

TORRO THUNDERSTORM REPORT: May-June 1988

By ADRIAN C. JAMES

Thunderstorm Division, Tornado and Storm Research Organisation,
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May was warm with an average amount of thunder. Because of the local nature of most of the thundery outbreaks, the distribution of thunder-days tended to vary considerably from place to place even within the same region. Over the north Midlands and central northern England four or five days with thunder were recorded at quite a number of observing stations, largely due to the surface warming of unstable southerly airstreams as depressions became slow-moving to the west of Britain. Conversely, there was generally little thunder in areas adjacent to southern and western coasts where a cool wind was blowing onshore.

Thunder-days in May were as follows: (Averages refer to the period 1951-80).

May 1988	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	Total	Ave.
England	X	X	X	X	X		X	X							X			X	X				X		X			X	X	X	15	16.9	
Wales	X	X	X												X				X				X		X				X	X	9	8.6	
Scotland	X	X	X																				X	X					X	X	7	8.1	
Ireland		X	X									X	X										X	X	X			X	X		10	8.0	
Total	X	X	X	X	X		X	X				X	X		X			X	X				X	X	X	X		X	X	X	19	18.7	
Netherlands		X	X	X			X		X	X					X	X	X								X	X	X	X	X	X	16	14	
Belgium		X	X	X					X	X	X					X	X	X					X	X	X	X		X	X	X	16	-	

A deep, slow-moving depression which transferred from southern Ireland to the North Sea during the month's opening days originated a notably thundery spell in many parts of central and northern Britain. There was thunder on the south coast of Cornwall on the morning of 1st, but most of the storms occurred in the afternoon over north Wales and from the West Midlands northwards to the central lowlands of Scotland. These fast-developing, low-level storms gave rise to short but spectacular displays of forked lightning in hilly districts, with fatal consequences for a number of week-end walkers. At Caradoc Hill in Salop a man was killed by lightning when about 20 separate flashes struck the slopes from which he was fleeing. In the Lake District, a man was killed and two companions suffered burns when a walking party was hit by lightning on Helvellyn, while in

another incident on the same mountain two people were struck and burned by lightning at Red Tarn. One person was killed and three more were injured near the summit of Great Rigg Man. In Ambleside, two people escaped injury when their bungalow burst into flames after being the object of a lightning discharge, and the railway station at Bridgnorth was struck twice in storms over the West Midlands. Marble-sized hail damaged plants and gardens at Moel-y-Crio (Clwyd). Further thunder occurred on 2nd from the Midlands to Scotland, as well as in Clwyd and Co. Limerick. A couple were injured by lightning as they walked in woods near Alton (Staffordshire) and their Alsatian dog, which took the full force of the flash, was killed. Away from the south there was more thunder on 3rd, with the heavy thundery showers which arose over the Midlands around noon developing into a major system of storms as they moved north across the southern Pennines. In Sheffield, the premises of two firms together with a school were struck by lightning and sustained minor damage; at Hoylake (Merseyside) lightning tore apart several trees, and houses at Moreton and Birkenhead suffered by the same agency. Thunderstorms also affected Ireland where lightning visited itself upon a house in Belcarra near Straide in Co. Mayo. In the mid-evening, lightning over north-east France was observed from Herstmonceux (East Sussex). On 4th, thunder was mostly confined to the Midlands, central northern and eastern England. A car was destroyed by lightning in Coventry, with telephone and television sets being incapacitated in nearby houses. Lightning ignited an electricity sub-station in Willoughby-on-the-Wolds (Nottinghamshire) and did some mischief to a house in Sheffield. Only Stamford (Lincolnshire) registered thunder on 5th amongst a crop of showers over the north Midlands.

An anticyclone was receding over Scandinavia on 7th as very warm air deriving from North Africa began to advance northwards around a depression in Biscay. Scattered thunder over south-west England and the Channel Islands in the afternoon and evening was followed by heavy storms early in the morning of 8th over south-east England and East Anglia as the warm front traversed the region. A few further storms occurred during the morning in the London area, but as low cloud evaporated and temperatures rose along a sharp convergence zone, thunderstorms of tropical intensity were born over Hampshire in the mid-afternoon, moving north as the convergence line itself transferred east. The storms were fiercest in east Berkshire and Middlesex, where very heavy rain, adding to the overnight fall, resulted in considerable flooding. Houses in Reading and Bracknell were struck by lightning and golf-ball-sized hail fell at Cookham. The funnel clouds observed near Hayes (Middlesex) dispersed without reaching the ground. In storms over Lincolnshire, the village of Tinwell near Stamford experienced damaging floods as 57mm rain fell in two hours, and electricity supplies to some villages were disrupted when lightning struck power lines. All thundery activity had ceased by dusk.

Thunder was heard in Co. Mayo during the afternoon of 12th and at Aldergrove (Co. Antrim) in the early hours of the following day. On 15th, an upper trough was situated over south-east England and showers turned thundery at times over southern England and south Wales. The 18th saw the introduction of cool northerly winds behind a cold front which crossed southern England in the morning, bringing a little thunder overnight to the eastern side of the Pennines and

to south London and Surrey early in the day. Isolated thunderstorms in the early hours of 19th over south Wales and south-west England were associated with a cold pool moving south-east across the area. Some further thunder occurred in the south-west during the morning and over the Hampshire coast and Hampshire/Berkshire border in the afternoon. By 23rd a cold front was pushing across western Britain and thunder broke out over Ireland during the day. Towards evening, there were storms at Laurieston (Dumfries & Galloway) as well as in south Wales and the Forest of Dean. Lightning damaged equipment at St. Briavels (Gloucestershire) and caused a power failure in 650 homes. There was thunder in Ireland and south-west Scotland on 24th and at Aldergrove in the early evening of 25th, when thunder may also have been heard in east Kent as a thundery low from France moved close to the region. The 26th was a showery day with some thunder in the late afternoon and evening over Ireland, together with the coasts of north Somerset and west Glamorgan. On 29th a trough was moving northwards within a broad area of low pressure, and thunderstorms developed rather widely over Britain except in the extreme south. A tornado was reported 13km west-north-west of Thornaby (Cleveland), and at Lancaster hailstones of 21mm diameter fell during a storm in the later afternoon. Hail and thunder were observed in some of the heavy showers which broke out in central and eastern parts of England on the afternoon of 30th, when thunder also occurred around Merseyside and at a few places in Ireland. A trough which moved east early on 31st gave thunder in Cardiff, and the heavy showers that developed in its wake turned thundery over central northern England, the north-east and East Anglia during the late morning and afternoon. Thunder was reported from southern Scotland in the evening.

Thunder-days in June were as follows:

June 1988	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	Total	Ave.
England		X	X	X																X								X	X	X	7	15.4
Wales																												X		X	2	7.7
Scotland		X	X																									X	X	X	5	8.7
Ireland		X	X																												2	7.5
Total		X	X	X																X								X	X	X	7	17.2
Netherlands	X		X	X	X						X										X						X	X	X	X	10	14
Belgium	X			X	X						X	X															X	X	X	X	9	-

The occurrence of thunder was well below average in June. The month's weather was predominantly anticyclonic and dry, only 7 days with thunder being reported from the British Isles as a whole compared with the 1951-80 average of 17.2 days. Many observers in central and eastern England noted two or three thunder-days, and a few places to the south and west of London had four; but most of northern and western Britain experienced no more than one day with thunder during the month.

Showers became thundery in the late afternoon of 2nd over Cos. Armagh and Antrim in Northern Ireland, and thunder was also heard over Humberside and the Moray Firth during the evening. A cold pool was located above Ulster by noon on 3rd, and Cookstown (Co. Tyrone) suffered heavy thunderstorms, with hail being swept into drifts which lay unmelted on road-side verges for several hours. Parts of

the Midlands and northern England, together with Edinburgh and Fife, shared in the afternoon's thundery activity, and another storm occurred over Bristol towards midnight. A very showery and rather cool northerly airstream prevailed across England on 4th, and thunder became widespread from the Midlands to south-east England with hail and squally winds in places. The storms progressed steadily southwards to clear the coast of Hampshire before dusk. Rain fell rather heavily in the west of Britain through the early hours of 7th, when sheet lightning was seen to the south of Constantine in Cornwall. There were no further thundery outbreaks anywhere in Britain until 20th, which saw the development of storms in a slack area of low pressure over England. Flash floods in south Oxfordshire and central Berkshire were a consequence of a heavy afternoon storm, accompanied by hail, which caused alarm at Battle Hospital in Reading as water leaked through the roof of the operating theatre. During the evening, the local fire brigade was engaged in evacuating water from houses at Maldon (Essex) flooded by a lengthy storm over central and eastern regions of the county. The press reported that about 45mm rain had fallen within two hours. On 26th, a single flash of lightning was noted shortly after midnight to the south-west of Wishaw (Strathclyde) within an area of rain over southern Scotland. Warm afternoon sunshine and increasingly unstable air initiated local thunderstorms in mid-Wales and Hereford on 28th. Towards midnight a thunderstorm was reported from Fair Isle, and this transferred south-west to Orkney through the early hours of 29th. Another storm broke out over Dartmoor to affect Exeter later in the night. More thunder occurred during the day over the north Midlands and the Pennines as well as the east of the Bristol Channel. A house was struck by lightning at Belper (Derbyshire) and a tree received a flash at Kedleston.

As a cold front approached Britain from the west, warm thundery weather moved north-north-east from Spain over western France early on 30th, with thunder reaching Ventnor on the Isle of Wight during the morning. Thunderstorms from northern France arrived in east Kent and Essex in the afternoon by which time thunder was widespread over central and northern England, while some thunder also broke out over north Wales and the Grampian region of Scotland. In parts of northern England the thunderstorms were severe and prolonged; one which descended upon York in the evening was described as the worst to hit the locality for many years. Outside the city's Museum Gardens five people were knocked to the ground when lightning struck the tree under which they had been standing, and one person, a special constable, suffered burns to his face. Also in York, two houses were damaged by lightning and a wall on a building site was struck and summarily demolished. Elsewhere, lightning injured a boy on Formby beach (Merseyside), and chimney stacks on two houses in Derby were the targets of lightning flashes, as were the roofs of two houses in Middlesbrough (Cleveland). As the storms drifted on to Northumberland, another region of thunder made landfall on the Hampshire coast and moved north-east to the west of London. South-western districts of Scotland and Wales heard thunder in the middle or latter part of the evening.

Acknowledgements: The Directors would like to thank all TORRO observers who have contributed to the compiling of these monthly reports. Sincere thanks

are also offered to observers of the Thunderstorm Census Organisation, the Climatological Observers Link and also to the London Weather Centre for information published in the *Daily Weather Summary*.

WORLD WEATHER REVIEW: August 1988

United States. *Temperature:* warm almost everywhere; +2degC from Iowa to N. Virginia; Cape Cod area, N.E. California, N.W. Nevada. Cold in parts of W. and S.W.; -1degC in E. Oregon, S. New Mexico, S.W. Texas. Hawaii near normal. *Rainfall:* wet from Arizona and W. New Mexico through Minnesota to Maine; coastal areas from extreme E. Texas to N. Carolina; W. Missouri. Over 200% in E. Arizona, S.W. New Mexico, S.W. Nebraska, N.E. Minnesota, N.W. Michigan; very locally in coastal S.E. Dry elsewhere; under 50% in almost all the N.W. quarter; much of Texas to S. Kansas; C. Arkansas to S.W. Tennessee; S. Illinois, S. Indiana, Cape Cod area. Under 25% in much of N.W., where there were many forest fires.

Canada and Arctic. *Temperature:* warm in most of Alaska and Canada; N. Greenland, Iceland; +2degC in interior Alaska, Ellesmere Island and near Coronation Gulf (N.W. Canada). Cold in extreme N. Alaska, Quebec, S. Greenland, Bear Island, Franz Josef Land; -2degC in N. Quebec. Spitzbergen near normal. *Rainfall:* wet in much of Alaska and Canada; W. and S. Greenland, E. Iceland. Over 200% from Calgary to Prince Albert (S. Canada); locally in S. coastal Alaska and E. Baffin Island. Dry in S.W. Alaska, lower Mackenzie basin, E. Greenland, W. Iceland, Jan Mayen, Bear Island, Franz Josef Land; parts of Keewatin Territory; most of extreme S. Canada. Under 50% in lower Mackenzie basin, extreme S. British Columbia and Saskatchewan, C. Alberta, S. Manitoba, S.E. Quebec, E. Greenland, Bear Island, Franz Josef Land.

South and Central America. *Temperature:* warm in most of South America 15-40°S.; N.W. and C. Mexico; Bahamas; +2degC in S. Brazil and parts of Paraguay. Cold in W. Bolivia, Uruguay, C. Argentina, C. Chile, interior N. Mexico, parts of S. Mexico to W. Honduras; -2degC in interior N. Mexico. *Rainfall:* wet in C. Chile, parts of E. Argentina, most of Mexico to S.W. Honduras; Bahamas. Over 200% locally in C. Chile, E. Argentina, Mexico, in and near E1 Salvador; Bahamas. Dry in most of South America 15-40°S.; parts of N. Mexico. Under 50% in Bolivia, S. Brazil, Paraguay, N. Chile, N. and parts of C. Argentina, S. Uruguay.

Europe. *Temperature:* warm from E. Spain to Germany, Poland, Romania N. Greece and S. Ukraine; C. Norway, E. European Russia; +2degC in S. Yugoslavia, S.W. Bulgaria, S. Urals; locally in Austria and N. Italy. Cold elsewhere; -1degC in Portugal, S. Eire, S.W. England, Athens area, C. Sweden to C. Volga basin. *Rainfall:* wet from much of British Isles through S. Norway and C. Sweden to Finland and much of European Russia; E. Poland, S. Germany, Austria, N. Hungary, N.E. Italy, N.W. Yugoslavia, much of Czechoslovakia. Over 200% in S. Finland and S.E. of Leningrad; locally in Czechoslovakia and N. Hungary. Dry elsewhere; under 50% in N. Norway, C. Urals, N.W. Poland, N. Germany, W. France, Spain, Portugal, S. Italy, Corsica, Sardinia, S. Ukraine; most of Balkans; parts of Caucasus. Rainless in S. half of Iberian Peninsula. Provisional sunspot number 111.

Africa. *Temperature:* warm almost everywhere from Maderia and Canary Islands to Egypt and in and near South Africa; +2degC in E. Morocco, N.W. Algeria and parts of Cape Province, Transvaal and Natal. *Rainfall:* wet in W. Cape Province (over 200%), E. Transvaal and S. coastal Natal. Under 50% in most other parts of South Africa; mostly rainless from Canary Islands to Egypt.

Asiatic U.S.S.R. *Temperature:* warm from C. Ob basin to Uzbekistan; C. Siberian Plateau to L. Baikal and Amur basin; +3degC near Sverdlovsk and near L. Baikal. Cold elsewhere; -2degC E. of Lena basin. *Rainfall:* mostly wet; over 200% in Kazakhstan and numerous scattered areas from C. Siberian Plateau to W. Kamchatka. Dry in S. Uzbekistan, E. Turkmenistan, Tadzhikistan, Ob basin to Taimyr Peninsula; N.E. of L. Baikal; E. Kamchatka to near Wrangel Island. Under 50% locally in last two areas; more widely in the others.

Asia (excluding U.S.S.R.). *Temperature:* warm in W. Turkey, W. and S. Pakistan, N.E. and parts of S.E. China, Korea, Japan, Thailand, Philippines; most of Arabia and India; +2degC in N.E. China;

locally in N. Philippines. Cold in E. Turkey, Israel, N. Pakistan, N. and part of S.E. India, Bangladesh, much of China; -2degC in E. Turkey and several places in China. Malaysia near normal. *Rainfall*: wet in E. and locally in S.W. Turkey, S. Pakistan, S. and extreme N. India, N. Bangladesh, Sarawak, S. Philippines; much of E. China and Japan. Over 200% at least locally in all these areas (except possibly N. India, Bangladesh and Philippines); more widely in S. Pakistan, S. India, S.E. China, C. Japan. Dry from most of Turkey through Middle East to N. Pakistan, much of N. and C. India and S. Bangladesh; N.W. and parts of E. China, N. Philippines. Under 50% locally in N. Pakistan and C. India; more widely in the other areas (except perhaps Bangladesh); Middle East largely rainless. Mainland S.E. Asia mixed, but no large anomalies.

Australia. *Temperature*: warm everywhere except very marginally near Alice Springs; +2degC in parts of Queensland and near N.W. Cape. *Rainfall*: wet in Queensland and near N.W. Cape, Darwin and Alice Springs; over 200% in all these areas, including most of Queensland. Dry elsewhere, mainly under 50%.

M.W.R.

WEATHER SUMMARY: October 1988

Mean temperatures in October were not far from the normal anywhere in the United Kingdom but with a tendency towards a slight negative anomaly over Scotland. Highest maxima reported were 21.5° at East Malling and 21.2° at Anvil Green, both on 18th and 22.3°C at Dover on 20th, all in Kent. In the north the temperature rose to between 18° and 19°C in the far west of Scotland and around the Moray Firth on 15th and 20.1° was recorded at Valley (Anglesey) on the same day. A minimum of 16.3° was recorded at Prestatyn (Clwyd) on the morning of 25th with 15.3° and 14.8° at Birdham and Worthing (West Sussex) on 27th and Turnhouse airport, Edinburgh, on 3rd. Lowest maxima were restricted to the closing days of the south. On 28th and 29th the temperature at Glenlivet (Grampian) rose to just 4.1° and 3.5° respectively, while in England 4.5° was the highest reached at High Bradfield (South Yorkshire) on 29th and 5.0° at Buxton (Derbyshire) on 30th. The temperature fell to as low as -8.5° at St. Harmon (Powys) on 31st, -6.7° having been recorded at the same station on 30th. Other low minima included -5.7° at Eskdalemuir (Dumfries and Galloway) on 29th, -4.3° at Velindre (Powys) on 30th and -5.2°C at Elmdon on 31st. The grass temperature fell to -11.1° at Glenlee (Dumfries and Galloway) on 31st, -10.5° at Shawbury (Shropshire) and -9.8° at Straide (Co. Mayo) on 30th, -9.2° at Turnhouse airport on 29th and -7.1°C at Inverdrue (Highland) as early as 11th. Rainfall was substantially above the average in many parts of the country but with a few exceptions, notably in parts of the Midlands, where it was quite a dry month in places, and on the coast of East Anglia where little more than half the normal rainfall fell. Some particularly high 24-hour totals were a feature of the month and included 58.6mm at Kilmallock (Co. Limerick) on 10th, 58.3mm at Diabaig (north-west Scotland) on 7th, 56.6mm at Sefton Park, Liverpool, on 19th, 53.3mm at Broadford, Skye, on 8th, 52.5mm at Coniston (Cumbria) on 18th, 50.7mm at Bastreet (Cornwall) on 5th and 47.0mm at Nantmor (Gwynedd) on 26th. Sunshine was generally a little above the average over most central and western parts of the U.K. but below in the east and in parts of Cornwall and west Devon.

With an anticyclone over the southern Baltic and with a ridge to southern Britain much of England and Wales had a dry start to October but a slow-moving

frontal system over Scotland and Ireland kept these parts cloudy and windy with some rain. A depression moved east into Ireland on 4th, giving some rain in the west, but on 5th and 6th a much more mobile weather pattern became established and active fronts crossed the country followed by strong westerly winds which carried heavy and sometimes thundery showers to all parts. Spells of often heavy rain, accompanied by very strong winds, affected all parts until 9th followed on 10th by a much drier day with good sunny spells, particularly in the south. On 11th and 12th a depression moved north-east into England, accompanied by a further spell of rain, but over the next few days, as an anticyclone pushed south-westwards from Scandinavia, it became much more settled with overnight fog and some local frost. A depression to the south-west pushed warmer air northwards across all parts on 18th but the weather turned more unsettled as heavy thundery showers or longer spells of rain fed across the country from Biscay over the next few days. It remained quite warm in all parts. On 27th and 28th a major change of weather type took place as much colder weather spread south on the western flank of a depression moving south-east into Scandinavia. Snow showers fell in the Northern Isles and over some of the Scottish mountains and from 29th to 31st, as an anticyclone settled over the country, most parts of the U.K. were cold and dry with a good deal of sunshine but with widespread frosts at night.

K. O. M.

TEMPERATURE AND RAINFALL: OCTOBER 1988

	Mean				Grass				Rain	%	Wettest	RD	Th
	Max	Min	Max	Min	Max	Min	Max	Min					
BELGIUM: Uccle	14.9	8.4	21.2(18)	-0.1(31)	-3.5(30)				72.2	102	21.8(6)	16	-
" Rochefort	15.8	5.8	24.2(18)	-5.0(31)					102.4	146	28.0(6)	15	-
" Houwaart	15.4	5.4	19.8(19)	-5.0(31)	-7.8(31)				62.5	85	19.0(6)	15	2
DENMARK: Fanø	12.0	6.7	15.3(3)	-2.3(30)					89.6	93	21.8(13)	15	0
" Frederikssund	11.7	5.3	16.5(2)	-6.0(25)	-7.7(25)				50.8	91	8.8(7)	15	0
GERMANY: Berlin	13.8	6.7	20.0(5)	-2.5(31)	-4.2(31)				19.7	49	5.2(8)	13	0
" Hamburg	12.8	6.3	19.4(27)	-1.1(30)	-4.0(30)				57.5	100	11.1(7)	16	0
" Frankfurt	14.8	7.6	20.5(9)	-2.9(31)	-4.4(31)				66.6	128	34.6(6)	12	0
" Munchen	14.0	7.0	21.5(18)	-2.0(31)	-5.4(31)				50.3	87	8.9(29)	18	0
ITALY: Casalecchio	19.6	13.3	24.0(1)	8.0(31)	6.0(31)				37.0	45	25.0(12)	5	3
MALTA: Luqa	25.1	17.9	27.1(7)	13.3(28)	9.0(28)				32.7		8.8(22)	6	3
NETH'NDS: Ten Post	12.9	7.6	18.0(27)	1.7(30)	-1.7(11)				80.8	116	17.6(7)	12	2
" Schettens	13.2	8.1	17.2(3)	2.4(11)	-1.0(30)				62.4	83	20.0(10)	13	2
" De Bilt	14.4	7.4	19.5(14)	0.0(30)	-4.0(30)				59.0	86	16.6(9)	13	3
" Lemmer	13.3	7.5	17.8(14)	1.8(30)	-0.5(30)				85.5	116	21.6(9)	14	3
SWEDEN: Valla	9.5	2.2	15.0(4)	-7.6(30)					45.4		10.9(9)	12	0
SWITZ'LAND: Basel	16.0	8.1	25.4(9)	-0.6(30)					106.2	98	9.1(9)	14	1
EIRE: Galway	13.8	7.9	18.8(15)	0.1(v)					104.3	81	19.2(21)	22	0
" Straide	13.1	5.8	17.0(15)	-3.7(30)	-9.8(30)				127.0	105	20.5(10)	21	1
SHET'AND: Whalsay	10.3	7.1	14.2(2)	1.1(11)	-2.2(11)				161.7	163	51.4(6)	27	0
" Fair Isle	10.3	7.7	13.4(2)	0.4(29)	-1.0(11)				106.9	102	20.3(25)	23	0
SCOT'AND: Braemar	10.0	3.4	14.4(2)	-4.1(30)	-6.2(30)				130.2	150	25.4(25)	21	0
" Inverdrue	11.0	3.1	15.4(15)	-4.2(11)	-7.1(11)				79.4	87	17.7(7)	19	0
" Rannoch	10.5	3.4	15.6(15)	-3.1(30)	-4.0(30)				175.5		30.6(25)	22	0
WALES: Pembroke	14.5	8.5	17.2(2)	2.9(29)	2.0(29)				156.2	139	27.2(26)	20	1
" Velindre	13.5	6.0	16.8(24)	-4.3(30)	-8.1(30)				90.8	14	24.3(11)	17	3
" Carmarthen	13.7	7.8	16.6(18)	-0.1(30)	-2.3(31)				137.7	106	19.1(26)	19	0
" Gower	14.0	8.8	16.1(18)	1.2(30)	-2.4(30)				123.3	92	19.6(5)	20	0

	Mean		Max	Min	Grass		Rain	%	Wettest	RD	Th
	Max	Min			Min	Max					
GUERNSEY: Airport	14.8	11.4	17.5(26)	6.8(31)			112.3	139	33.2(12)	13	1
ENGLAND:											
Denbury, Devon	14.5	8.3	18.0(26)	2.0(1)	0.2(1)	131.0	130	39.8(18)	18	0	
Yatton, Avon	15.1	8.0	17.9(23)	-1.7(30)	-4.4(30)	90.5	87	23.8(8)	16	1	
Corsham, Wiltshire	14.3	7.3	17.1(22)	-1.4(30)	-4.8(30)	94.6	135	17.9(8)	16	3	
Mortimer, Berks	14.5	7.1	17.5(26)	-2.2(30)	-6.0(30)	78.7	127	24.2(8)	15	0	
Reading Univ., Berks	14.8	7.6	18.2(18)	-1.8(30)	-5.8(30)	75.8	138	24.2(8)	13	0	
Sandhurst, Berkshire	15.2	7.5	18.9(18)	-2.2(31)	-2.8(31)	78.2	119	22.4(8)	12	1	
Romsey, Hampshire	15.4	7.3	19.5(3)	-0.5(1)	-4.9(30)	94.4	119	28.3(8)	15	2	
Horsham, Sussex											
Brighton, Sussex	15.1	9.2	19.7(18)	3.3(30)	2.5(30)	88.5	76	31.6(8)	12	0	
Hastings, Sussex	14.9	9.4	19.9(18)	3.3(29)	1.4(29)	94.1	140	23.2(5)	11	1	
Dover, Kent	15.5	8.7	22.3(20)	0.9(1)		100.9	117	20.3(8)		3	
East Malling, Kent	15.6	8.2	21.5(18)	0.0(1)	-5.0(30)	65.1	101	18.5(8)	12	1	
Epsom Downs, Surrey	14.7	7.9	19.6(18)	-1.5(30)	-5.2(30)	66.2	77	20.2(8)	13	0	
Reigate, Surrey	14.9	7.9	19.8(15)	-0.1(1)		58.2	98	20.5(8)	14	0	
Guildford, Surrey	14.7	8.4	19.5(18)	-1.0(30)	-3.1(30)	60.3	83	21.6(8)	13	0	
Sidcup, London	15.3	8.1	19.0(19)	-1.5(31)	-3.8(31)	62.5	116	18.8(8)	12	0	
Hayes, London	15.1	7.7	18.8(19)	-1.3(31)	-3.1(31)	63.8	89	20.2(8)	11	2	
Hampstead, London	14.7	9.1	18.4(19)	1.5(30)	-3.0(1)	67.1	112	25.2(8)	11	0	
Royston, Hertfordshire	14.4	8.5	19.8(19)	-1.0(30)	-5.6(30)	38.6	78	10.3(8)	15	0	
Loughton, Essex	14.3	7.7	18.9(19)	0.3(31)	-4.1(31)	69.7	110	18.7(8)	12	2	
Buxton, Norfolk	14.1	7.2	18.2(2)	-1.2(31)	-2.4(31)	42.8	75	9.0(18)	13	2	
Ely, Cambridgeshire	14.3	6.8	19.5(19)	-2.3(30)	-3.0(31)	35.7	67	7.7(9)	13	2	
Luton, Bedfordshire	14.4	7.4	19.0(19)	-2.9(31)	-7.2(31)	58.5	100	15.2(8)	14	1	
Buckingham, Bucks	14.3	6.8	18.3(19)	-2.6(30)	-7.8(30)	42.1	67	9.5(8)	13	0	
Oxford University	14.5	7.9	17.4(19)	-0.7(30)	-6.0(30)	38.6	60	9.6(8)	13	-	
Churchdown, Glos	14.4	6.7	18.9(2)	-4.4(30)		68.1	104	14.4(12)	15	3	
Stourbridge, W.Mid'nds	13.3	7.5	17.5(19)	-2.2(31)	-7.7(31)	46.9	50	10.0(18)	13	1	
Birmingham Univ'sity	13.1	6.8	17.3(19)	-2.9(30)	-7.6(30)	51.6	86	11.1(18)	15	2	
Wolverhampton	12.0	6.8	16.6(19)	-2.9(30)	-5.8(30)	50.3		11.6(18)	18	1	
Kettering, Northants	14.0	6.4	19.4(19)	-4.3(30)	-6.7(30)	46.8	86	10.1(19)	16	2	
Louth, Lincolnshire	13.4	7.0	16.5(2)	-0.3(31)		77.0		29.7(19)	12	1	
Keyworth, Notts	13.7	7.5	19.3(19)	-2.7(30)	-6.7(31)	40.6		14.2(19)	18	2	
Nottingham, Nott'shire	14.2	6.9	19.2(19)	-2.6(31)	-4.1(31)	34.7	78	11.0(19)	17	2	
Derby, Derbys	13.8	8.0	18.8(19)	-1.2(31)	-2.7(31)	67.6		15.3(19)	19	2	
Middleton, Derbyshire	11.2	6.4	16.1(19)	0.1(30)		92.3	99	13.7(19)	20	1	
Keele University, Staffs	12.7	6.9	16.8(19)	-0.9(30)	-6.0(31)	57.4	82	14.2(18)	15	1	
Liverpool, Merseyside	13.7	7.0	17.8(19)	-2.7(31)		147.5	200	56.5(19)	18	2	
Lathom, Merseyside	13.5	7.4	18.2(19)	-1.9(30)		76.5		15.6(26)	16	-	
High Bradfield, S.Yorks	10.7	6.4	14.0(19)	-0.4(29)		90.5		25.3(6)	20	-	
Cottingham, Humbside	14.0	6.9	17.9(3)	-0.9(31)	-3.8(31)	51.8	98	11.6(20)	13	1	
Carlton-in-Cleveland	12.7	7.1	15.8(2)	-1.7(31)	-5.7(29)	66.7		20.1(18)	15	0	
Sunderland, Tyne/Wear	12.8	8.1	16.5(3)	1.3(29)		67.9	128	11.1(26)	17	0	
Carlisle, Cumbria	13.2	7.3	18.0(19)	-2.9(31)		73.2	90	10.0(9)	21	0	
CANADA: Halifax	13.4	5.5	21.0(3)	-0.5(31)		250.2		50.2(19)	14	2	
U.S.: Bergenfield, NJ	15.7	4.9	26.1(1)	-3.9(31)		76.5		36.8(22)	5	0	
AUSTRALIA: Leopold	20.1	8.2	26.5(3)	5.1(v)		22.8	41	9.3(2)	5	0	

CUMBRIA RAINFALL:

The Nook, Thirlmere, 279.2mm (107%); Coniston, 287.2mm (114%); Hawkshead, 216.4mm (119%); Sellafield, 112.5mm (100%).

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