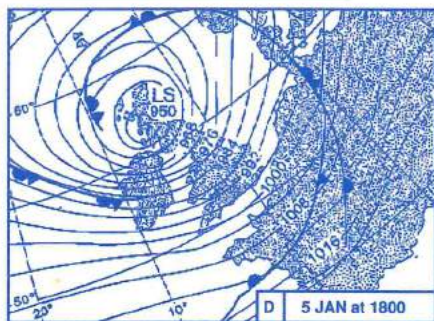
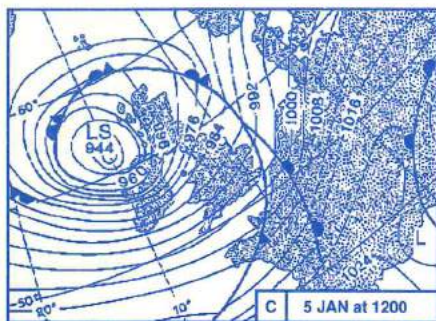
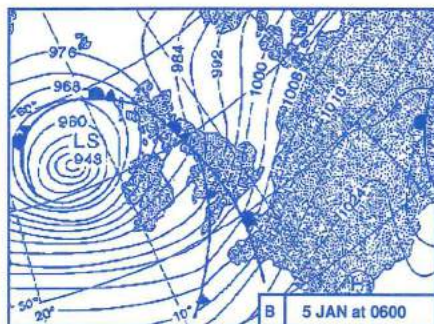
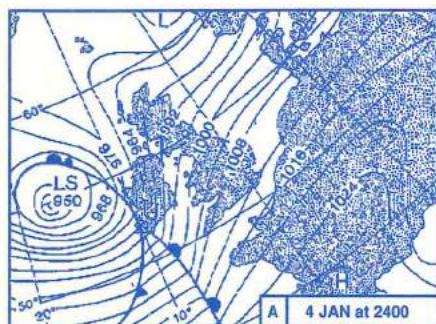


The
JOURNAL of METEOROLOGY



*SYNOPTIC CHARTS FOR 5 JANUARY 1991
WHICH BROUGHT STORM-FORCE WINDS TO NORTHERN IRELAND*

THE JOURNAL OF METEOROLOGY

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STORM-FORCE WINDS OVER IRELAND, 5 JANUARY 1991

By NICHOLAS L. BETTS

School of Geosciences, The Queens University of Belfast, Northern Ireland

Abstract: Storm force winds and heavy precipitation accompanying the passage of an intense frontal depression across northern Britain on 5 January 1991, caused damage and disruption throughout the island of Ireland. The synoptic event is outlined, and its impact described. Media claims of a trend towards increased storminess and an absence of a co-ordinated plan to cope with severe storm events, are also commented upon.

INTRODUCTION

With the passage of a vigorous depression over northern Britain on 5 January 1991, much of the British Isles experienced severe wind strengths, and fourteen weather-related deaths occurred in Ireland alone. The synoptic event and its impact upon the island of Ireland are here outlined. Some consideration is also given to concerns reported by the media relating to changes in frequency of notable events, and the apparent inadequate dissemination of information and advice to the general public on such occasions.

SYNOPTIC DEVELOPMENT

At the beginning of January 1991, low pressure dominated the surface synoptic circulation over the North Atlantic poleward of latitude 55°N, resulting in a strong zonal airflow across the British Isles. Within the southern sector of this cyclonic circulation, a depression formed off Newfoundland on 3 January, and by mid-day on the 4th, with vigorous deepening (968hPa), had moved to 53°N 28°W. With continued rapid eastward movement, by 2400 GMT on the 4th the depression had deepened considerably (950 hPa), and lay some 400km west of Ireland (Figure 1). The associated frontal system, in the process of occluding, was affecting the extreme southwest of Ireland, where continuous rain and gale force winds were reported.

By 0600 GMT on the 5th the depression was centred at 56°N 14°W, and the frontal system having crossed Ireland, was now aligned north-south over western areas of mainland Britain. Continued deepening of the system (943hPa), and a strengthening pressure gradient on its southern flank was producing gale force winds throughout western Ireland.

With the storm centred less than 100km off the Donegal coast at mid-day on the 5th (944hPa), further intensification of the pressure gradient over Ireland during the afternoon, resulted in 10-minutes average wind speeds of storm force

over coastal areas of Counties Donegal and Mayo, and strong gale force winds generally. Gusts in excess of hurricane force were recorded at most anemograph sites throughout Ireland. Table 1 represents the highest 10-minutes average wind speeds, and the highest gust speeds recorded at selected sites during the event. Wind speeds were markedly greater at exposed coastal sites, decreasing with distance inland, due to the land exerting a greater frictional force upon the surface wind than the ocean. Furthermore, wind strength generally in Northern Ireland was less severe than that experienced in the Republic, owing to the sheltering effect of the surrounding mountains of Sligo, Leitrim and Donegal.

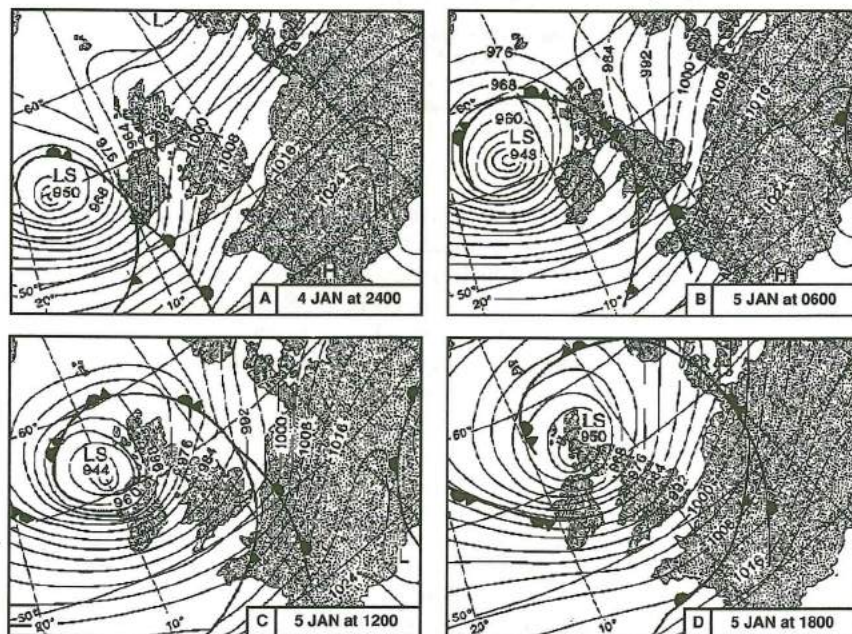


Fig. 1: Surface synoptic situation during the most intense period of the storm of 5 January 1991. (Based upon *Daily Weather Summary*, London Weather Centre).

Through the remainder of the day the depression continued to track eastward across Scotland, maintaining severe gale force winds across Ireland. Only as the storm moved into the North Sea early on the 6th, did a slackening pressure gradient develop over much of the British Isles.

Heavy precipitation on the 5th resulted in parts of Northern Ireland receiving in excess of 20mm during the 24-hour rainfall-day. Western and northern areas of the Province affected by thunderstorms in the latter part of the day, received the greatest falls, with Carrigans (County Tyrone) recording 30.3mm, most of which occurred between 1200 on 5th and 0900 GMT on 6th.

Table 1: Maximum wind speeds at selected anemograph stations in Ireland on 5 January 1991.

STATION	COUNTY	HEIGHT OF VANE ABOVE M.S.L. (metres)	MAX. 10-MINUTES MEAN (kn)	MAX. GUST (kn)
Ballypatrick Forest	Antrim	165	36	59
Belmullet	Mayo	9	54	83
Birr	Offaly	70	34	64
Clones	Monaghan	87	40	65
Dublin	Dublin	65	50	72
Malin	Donegal	24	49	68
Orlock	Down	51	45	66
Rosslare	Wexford	24	39	63
Valentia	Kerry	17	43	71

STORM IMPACT

Of the fourteen deaths in Ireland resulting from the storm force winds of the 5th January 1991, falling trees were responsible for ten fatalities in four separate incidents. The worst of these occurred near Portuma, County Galway, when a tree crushed a minibus, killing seven of its eight occupants.

Coastal settlements, particularly in Counties Donegal and Sligo experienced structural damage, since these areas bore the brunt of the storm force west/south-west winds. The degree of disruption to communications and power lines, and the extensive flooding of lowland farms in Midland counties, resulted in the synoptic event being considered in Eire, as one of the worst storms on record. The effects were compounded by a severe cold spell that followed, with heavy snowfalls hampering the re-opening of communication networks, and the restoration of energy supplies.

In Northern Ireland major structural damage was not widespread, roofing mainly being affected. Unconfirmed reports, however, suggest that a tornado was responsible for damage to thirteen caravans at a site near Ballywalter on the Ards Peninsula. Storm force winds felled trees throughout the Province, with many routes impassable. A combination of abnormally high spring tides and exceptional wave heights breached a sea wall along a section of Strangford Lough, resulting in the closure of the road between Portaferry and Newtownards. Tidal surges also encroached sea defences at Carrickfergus on the shore of Belfast Lough, and along the Antrim coast between Glenarm and Carnlough. With the curtailment of ferry services, sea communications with Great Britain were interrupted, but airports remained operational.

Windblown trees were responsible for the widespread failure of power supplies. Parts of Belfast experienced power cuts, but most adversely affected were remote rural areas of Counties Antrim, Armagh, Down and Fermanagh. Indeed, in the latter area, thunderstorm activity also contributed to the curtailment of energy supplies.

Compounded by the heavy rainfall of previous days, precipitation accompanying the storm force winds, particularly over upland, brought severe

flooding to the Cushendall area of County Antrim, where deposits of fluvial gravels and detritus from the October 1990 floods still covered many fields. Several hundred hectares of farmland in low-lying areas of Counties Cavan and Fermanagh were also flooded. Fortunately, many animals had already been housed for the winter, and of those remaining outside, warnings issued by the Met. Office meant that most farmers had taken the precaution of evacuating livestock from pastures at risk. Water-logged soil, however, posed a threat to yields from winter cereals, and early preparation of arable land in the spring.

The storm force winds also coincided with a series of IRA fire bombings of commercial and retail establishments throughout Northern Ireland. The weather conditions encouraged fires to spread rapidly, and become uncontrollable, with damage amounting to many millions of pounds.

THE STORM IN CONTEXT

The storm of 5th January 1991 was one of a number of very intense depressions over the North Atlantic sector in recent years (Burt, 1987; Rowe, 1990). Following this most recent event, there abounded local media conjecture concerning the apparent increased frequency of severe storms, and linkages with the global warming issue. Hammond (1990) however, has presented evidence to suggest that recent storm events are within the range of 'random' fluctuations to be expected in the long-term wind climate of the British Isles. As to an association of sustained high winds and frequent gales with the 'greenhouse' warming scenario, mid-latitude storms are driven by the equator-to-pole temperature gradient. With a probable reduction of this thermal contrast in a warmer world, Houghton *et al* (1990) and Rowntree (1990) state that some climate models indicate a weakening of mid-latitude storms and a tendency for mean wind speeds to decrease. It must be emphasised, however, that until higher resolution models become available, it will not be possible to predict the likely circulation changes during the transient response to global warming (Rowntree, 1990).

One further aspect of the storm on the 5th January 1991 was that despite very effective Meteorological Office forecasts and warnings, the event led to loss of life, destruction and general disruption throughout the island of Ireland. In Eire and Northern Ireland, the media claimed that emergency authorities were ineffectively organised to cope with meteorological events of this magnitude, and suggested the need for a storm warning service of the scale operative in the U.S.A. Such a programme to reduce the impact of the most significant weather events in the British Isles is neither necessary, nor cost effective. Recent emphasis, however, upon prediction and preparedness in meteorology and its allied disciplines is well exemplified in the special issue of *Weather* (April, 1990), which outlines how scientific and technical guidance is attempting to reduce human suffering in the event of weather-related disasters.

In Northern Ireland there exists no single co-ordinating body to organise emergency authorities, and offer guidance to the public. It has been suggested

that a government department be responsible for, at the very least, the issue of information pamphlets indicating the plan of action to be taken before, during, and after storm events. Particularly vulnerable are isolated communities in rural areas; and the dissemination of basic advice to households to ensure an adequate supply of drinking water, stocks of food that require no cooking or refrigeration, possession of battery-powered lighting, and a radio, would alleviate some of the stress incurred with curtailment of power supplies.

Acknowledgements. The author wishes to thank the Meteorological Office, Belfast, and the Irish Meteorological Service, Dublin, for providing climatological data, and is grateful to Mrs. G. Alexander for producing the line drawing.

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THE HEAVY EARLY-SEASON SNOWFALLS OF 7-9 DECEMBER 1990: PART II, HISTORICAL PRECEDENTS THIS CENTURY

By W. S. PIKE

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Abstract: An investigation of historical precedents indicates that the snowfalls of 7-9 December 1990 were, for parts of the English Midlands, a combination of the heaviest, earliest and most-widespread this century when associated with a single storm-complex.

INTRODUCTION

Have there been any previous snowfalls, associated with one storm or depression complex, which have been simultaneously (1) earlier, (2) heavier, and (3) more widespread anywhere in the UK this century?

EARLIER SNOWFALLS

Earlier snowfalls certainly exist. They start from August on the mountains of Scotland and can penetrate down to 1000 ft (300 m) a.s.l. by late September. Problems for motorists at high levels sometimes begin as early as October in strong northerly airstreams (e.g. "There were 3ft drifts at Glenshee on the Perth to Braemar road", according to *Weather Log*, early on the 28th October 1974. However, more generally in the UK, it is not usually before the third week of November that highway problems with snow become severe, widespread or long-lasting.

10 cm level depth (with 20 cm locally) affected Dartmoor on 17 November 1972, and similar accumulations were seen on the Derbyshire Moors (above 1000 ft) also on the 17th, in 1969. More widespread cover occurred as showery troughs affected east coasts districts of England during an exceptionally-cold northerly outbreak over 27th-28th November 1925, with "snow lying to a depth of 6, 7 and 10 inches being recorded at Hull, Norwich and Scarborough on the 28th" (*Meteorological Magazine*, 60, p272).

Two particularly snowy periods in November can be discounted because more than one storm system was involved. The beginning of the exceptional 1962-3 winter saw several falls (occurring over 16th-19th November) accumulating to "depths of 1 ft (30 cm) or more in many part of Scotland" (*Snow Survey of Great Britain*). Then in 1965, two fast-moving major depressions produced combined totals of 30-45 cm with 2-3 m high drifts accumulating over much of northern England and north Wales by 30th November. Both storms of the 27th and the 29th resulted in general falls of 15-20 cm, with 25 cm reported from Clewdd Newdd (Denbigh) on the 27th, and also at Slaidburn (West Yorkshire) on the 29th. Redmires (Nr. Sheffield) reported level depth of 44 cm, and Slaidburn 41 cm on 30 November 1965 (*Snow Survey of Great Britain*).

A particularly early 'easterly blizzard', associated with a warm front which approached from the south and then retreated again, affected much of the south Midlands on 29 November 1952, with 10-20 cm of snow piled into deep drifts from The Chilterns to South Wales. This snow added to the 18 cm which was already lying (since the 21st-22nd) in parts of Wales, leaving a total near 30 cm (25 cm at Evancoyd, Radnor), although a completely-fresh cover of 20 cm was reported from Little Rissington (on the Cotswolds) early on the 30th. There was much traffic dislocation, and Jackson (1977) mentions that "a train was snowed up".

To find an early fall approaching 35 cm we probably have to go back to November 1904, when 33 cm was reported from Langholm, Scotland, early on the 21st after heavy overnight snow associated with a rapidly-deepening depression which passed east-south-eastwards from the North Channel to Humberside. Immediately after its passage, further accumulations due to heavy showers in the strong northerlies soon increased depths to 45 cm in hilly areas of Southern Scotland, North-West England, and North Wales.

Moving into December, the 7th-8th has (coincidentally) seen several significant snowfalls in the UK - during 1937, 1967 and 1981. The most-recent 1981 case saw depths of 12 cm or less; and only 1967 approached the 1990 blizzard in terms of severity, extent and recorded snow depths, although it was not nearly so long-lasting. Falls on 7th December 1937 were more localised, principally affecting central southern England, with up to 30 cm blanketing areas from the New Forest to Salisbury Plain (Shaftesbury was cut off for a time). This was another early 'easterly' situation with an occlusion approaching from the south, then retreating again.

The first of two 'Polar Lows' travelling south-south-eastwards produced up to

45 cm in Snowdonia (e.g. at Capel Curig and Blaenau Ffestiniog, Gwynedd) overnight on 7th-8th December 1967. Snowfalls were fairly extensive but generally only 10-15 cm (although deeply drifted) over a broad swathe towards the Sussex Coast where they intensified again near to the sea. A photograph of the complete traffic jam on the Brighton to Rottingdean road (B259) in some 28 cm of snow (see Stevenson 1968) appear similar, although not so extensive, as the chaotic scenes described on the M6 motorway and other major Midlands roads in 1990.

Illustration of 'blizzard conditions' that were temporarily more-severe on 8 December 1967 in Avon came from RAF Colerne observations (altitude 165m a.s.l. near Bath) at 0805 UTC, with heavy snow, a northerly 25-knot wind gusting to 52 knots, and visibility 15 metres. The snow tapered steadily off to become light by 0900 UTC but the temperature had fallen to -5°C . The wind remained strong and drifts of nearly a metre were reported by 1100 UTC, and snow depth was 12 cm, rather more than in 1990.

Figure 1 is an anemograph record from Abingdon (where the author was working at the time) showing how the cold air acted as a 'density current' with

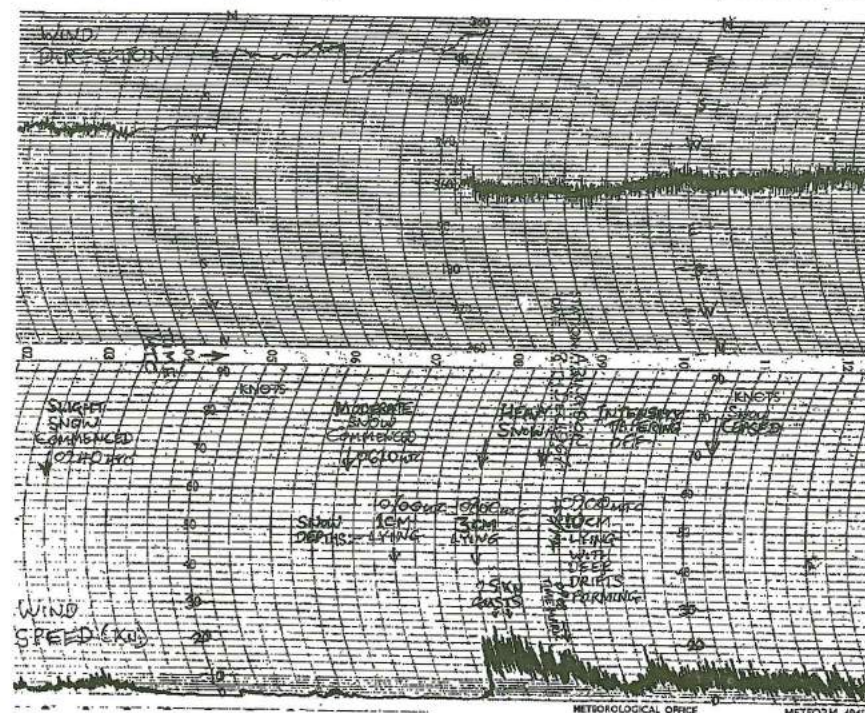


Figure 1: Anemograph record for Abingdon, South Oxfordshire (altitude 73m a.s.l.) during the snowfall of 8th December 1967 associated with a 'polar low', the most recent and closest precedent in the C.S. England area to the blizzard of 8th December 1990. From information in the Meteorological Office archives.

an instantaneous increase, then a steady tapering off of speed, behind a well marked front. With very low temperatures and drifting snowfall continuing for several hours, all Downland roads soon became blocked and it took the author seven hours to reach Woodlands St Mary (after his 'night shift') during the 8th.

HEAVIER SNOWFALLS

There have been many snowfalls heavier than 7-9 December 1990 in the UK, but these (with the exception of 1927 during the festive season) generally occur after Christmas. 18-19 February 1978 (in south-west England), 7-8 January 1981 (more widely in the south-west) and 24-26 April 1981 (see *J. Meteorology UK.*, 6, No. 61) being three recent examples. In Durham, what M. C. Jackson has recalled as "Prof. Manley's favourite snowstorm" was 20 February 1941, when 45 cm was reported in the county. Birmingham saw 36 cm as recently as 9th January 1982 at Edgbaston, although 41 cm appears to be the maximum recorded depth there, on 6th March 1947. It was a consequence of this severe winter (1946-7) that the 'Snow Survey of Great Britain' commenced making regular observations of snow depths. Edgbaston recorded 34 cm maximum in 1990.

Regarding pre-Christmas snowfalls in south-east England, the slightly later date of 11th December has seen 30 cm approached or exceeded in 1981 and in 1920, when local falls of up to 36 cm occurred around Clacton on the south-east Essex coast (*Meteorological Magazine*, 55, p286).

SUMMARY AND CONCLUSION

To summarise this discussion, in the UK, coastal areas have had more severe snowstorms this century that were earlier than 8th December 1990 (e.g., 7th December 1937 in Dorset; 11th December 1920 in south-east Essex; 28th November 1925 in Norfolk, Lincolnshire, Humberside and East Yorkshire; 29th-30th November 1952 in Gloucestershire; and 7th-8th December 1967 in North Wales, central southern England and Sussex). Although motorways were not then widespread, the 1967 occasion caused memorable road-traffic disruption and, in common with 1990, also saw questions regarding the ineffective use of road salt asked in the House of Commons (see *Weather*, 23, p256).

However, as regards the heavily-populated English West Midlands, the author failed to find any particular snowfall (associated with a single storm-system) which has been simultaneously (1) earlier (2) heavier and (3) more widespread this century, i.e., since 1900.

Acknowledgements: I wish to record my particular thanks to M. Wood (Archivist) and G. Northcott (Data Publications) plus their kind and helpful staff at the Meteorological Office Headquarters, Bracknell.

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FIFTEEN YEARS OF THUNDERSTORM OBSERVATIONS IN THE EPPING FOREST AREA

By R. J. PRICHARD

Abstract: All reports of thunder from Epping and Loughton in south-west Essex from 1976 to 1990 have been analysed. These show June to be the most thundery month and November the least thundery. Diurnally, thunderstorm activity peaks in the late afternoon and is at a minimum shortly before mid-morning. Some of the more severe and/or unusual thunderstorms observed during the fifteen years study are described. The most thundery year was 1983 and the least thundery was 1978, although 1989 and 1990 were the years with the fewest storms of any significance.

INTRODUCTION

The Epping Forest district of south-west Essex has one of the highest annual averages of 'days with thunder heard' in the British Isles. The problems with this statistic have been referred to in several articles, most recently by Mortimore (1990). There is no doubt that a keen observer can effect an increase in the local average by hearing distant thunder that many other people would miss; hence the need for a definition of 'nearby thunderstorm day'. However, even when this factor is taken into account, Epping Forest is, by British standards, a thundery area.

This article explores several aspects of the subject, describing both those situations that favour thunder in the area, and also those where other areas in southern Britain may be more likely to be affected. Severe thunderstorms are investigated, and a method for forecasting them is cited. Fifteen years of data from Epping and Loughton provide the source for this material.

The prime reason for this study is, purely and simply, interest and curiosity. But it is also suggested that much can be learnt about the British thunderstorm as a result, particularly when similar studies are carried out for other districts.

SEVERITY CODES

The author has written up reports of every thunderstorm he has observed since the mid-fifties, together with those at his home station of the time that he missed through being away but which were reported to him. At the outset, it was decided to give each storm a severity code from 1, most severe, to 7, weakest. This was not precisely defined, but has stood the test of time. Only rarely has 1 been assigned; there were three such storms in the 15 years of this study, all in June (14.6.77, 4.6.82, 1.6.83).

Code figure 5 reflects probably the lowest figure for the sort of storm that 'most people would be aware of' (see above). Code figure 7 will normally refer to very distant thunder (or lightning only, which is excluded from this analysis).

The author has always found there is considerable confusion amongst official observers of the weather as to what constitutes a 'heavy thunderstorm'; more than once he has been told by experienced observers that for a thunderstorm to be coded as heavy, thunder and lightning need to be frequent. Heavy thunderstorms are also often mis-coded by less experienced observers on the

basis of the intensity of the precipitation accompanying them.

All the author's interest and experience with the weather has been to try to tie its description to how people normally perceive it. Scientists are trained to define things precisely - but not everything can be defined precisely, and this is true very often with the weather. Attempts at such precise definition can then lead to nonsense. A one-flash storm that demolishes the chimney of your house cannot, on any common-sense basis, be defined as a 'slight thunderstorm'; the author would code it as '3' (two close strikes, both causing damage, could merit a '2'). Conversely, the sort of medium-level storm that rumbles away virtually continuously, but not very loudly even if overhead, might be coded as '4'; it should be noted that such a storm might be more impressive at night, on account of the frequent lightning, so might then merit a '3'.

This should give the flavour of the coding; it is based on common-sense. Would that more of our meteorological studies were.

TABLE 1: Monthly averages of days with thunder.

- (i) All observations of thunder (severity codes 1-7).
 (ii) Observations of thunder, severity codes 1-5.
 (iii) Observations of thunder, severity codes 1-2.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
(i)	0.40	0.47	1.20	1.93	3.60	4.07	3.20	3.20	2.33	1.00	0.13	0.40
(ii)	0.13	0.20	0.60	0.73	1.93	2.53	2.20	1.87	1.27	0.33	0.07	0.20
(iii)	0	0.07	0.07	0	0.13	0.40	0.27	0.13	0	0.07	0	0

MONTHLY AND ANNUAL VARIATION

Table 1 shows the monthly averages of days with thunder; table 2 and Figure 1 show the yearly totals and averages. For both monthly and annual variations, the tables show (i) all reports of thunder, (ii) observations of thunder with severity codes 1-5 and (iii) observations of heavy thunderstorms, codes 1 and 2.

TABLE 2: Annual totals and averages. (i), (ii) and (iii) as for Table 1.

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	MEAN
(i)	16	20	16	22	18	25	27	32	20	23	19	27	28	17	19	22
(ii)	12	16	11	8	11	17	18	18	13	16	8	13	13	7	4	12
(iii)	2	3	1	1	1	1	2	4	2	1	0	1	0	0	0	1

The most thundery month is June and least thundery November. The summer frequencies contain no real surprises, but there is an interesting contrast in the quieter part of the year with the figures produced by Atkinson (1966) in his study of thundery outbreaks in south-east England between 1951 and 1960 inclusive. He found that, with the exception of November, there was a continuous decline in frequency from October to February, and that the autumn season (October and November) had more outbreaks than either spring (March and April) or winter (December, January and February). The Epping Forest study shows quite different results. Thunder was only heard in two of the fifteen

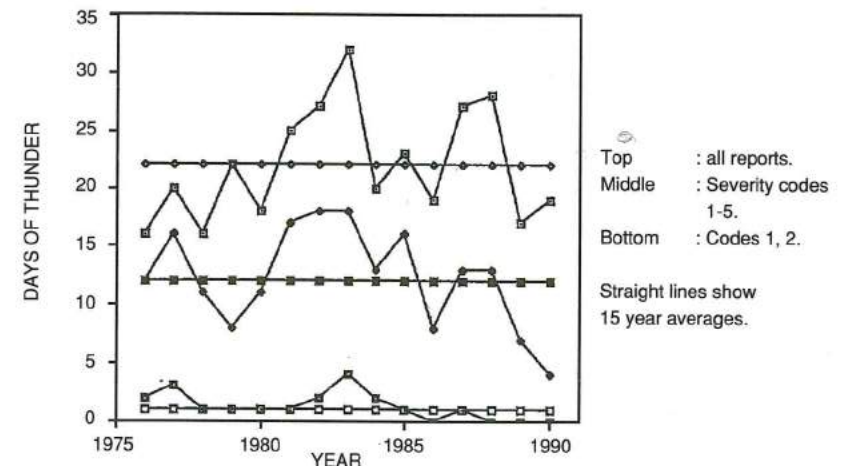


Figure 1: Annual total days with thunder in the Epping Forest area, 1976 to 1990.

Novembers, and spring is much more prone to thunder than is the autumn. Atkinson explained his results by the comment that they are "no doubt related to the higher temperatures and humidities in autumn". In fact it seems probable that the higher autumn frequencies he found are linked to the relative warmth of the English Channel at that time of year, favouring thunder over Kent and Sussex. Conversely, in spring, it is the warming up of the land that becomes important, and this favours more inland locations.

Annual totals range from 16 (1976 and 1978) to 32 in 1983. When the more trivial outbreaks are excluded, the range is from 4 in 1990 to 18 in 1982 and 1983. When the most severe thunderstorms are considered, 1983 again comes out top with 4 days. The five years 1986 to 1990 only produced one severe thunderstorm - on 22 August 1987.

TABLE 3: Times of day with thunder. Total number of occurrences with thunder in each hour (GMT).

HOURLY ENDING	01	02	03	04	05	06	07	08	09	10	11	12
Total	18	18	15	18	16	11	5	7	12	15	17	26
yearly average	1.20	1.20	1.00	1.20	1.07	0.73	0.33	0.47	0.80	1.00	1.13	1.73
HOURLY ENDING	13	14	15	16	17	18	19	20	21	22	23	24
Total	48	53	70	75	56	65	41	27	20	16	17	13
yearly average	3.20	3.53	4.67	5.00	3.73	4.33	2.73	1.80	1.33	1.07	1.13	0.87

DIURNAL VARIATION

Table 3 shows the hourly totals. Peak activity occurs in the hour to 1600 GMT. There is a marked increase in activity immediately after 1200, a marked decline after 1800. From 2100 to 0500, activity is at a low, but consistent, level

but it then dips to give minimum activity in the hour to 0700 (only five occasions in the fifteen years). Davis (1969), in a study of thundery activity at Heathrow between 1946 and 1968, produced broadly similar results.

SOME SEVERE THUNDERSTORMS

Thunderstorms were given a severity coding of 1 on three occasions. The amazing storm of 4th June 1982 was described in the bulletin of the Climatological Observers Link for that month; it gave 78.9 millimetres at the author's site in just under three hours, and some twelve properties in the area were struck by separate lightning flashes. There were 19 separate outbreaks of thunderstorms in June 1982 at Loughton. May 1983 was also exceptionally thundery, and culminated in a very fierce storm on the last night of the month in a very warm southerly airflow. Storms developed more or less simultaneously over the North and South Downs shortly after sunset, and quickly became widespread and severe. They lasted for some 7½ hours in the Epping Forest area and included some large hail that took the grass minimum temperature down to 3.3°C (air minimum was 11.9°C). There was a similar overnight, type 1, storm on 13th/14th June 1977.

Severity '2' storms are too numerous to describe; the one on 22 August 1987 was reported in the Journal of Meteorology for December 1987. Both type 1 and 2 storms have been responsible for flooding in the area, and this article also set out 'conditions for a severe Epping Forest storm'; there is no doubt that a certain type of severe storm can be predicted with some degree of confidence, although every summer is liable to contain two or three occasions when such predictions prove to be false alarms. Conversely, the storm that hit the northern part of the area (Epping and North Weald) on the 29th July 1987 and gave serious flooding did not fit the pattern, and it is not felt its severity could have been forecast. This storm was so localised that it did not show up accurately on radar. It is also, perhaps, the only example of a storm that merits a severity code 1 for Epping but not elsewhere in the area, including the observer's location at Loughton; the three that were so coded were much larger storm systems.

GENERAL COMMENTS ON THUNDERY SITUATIONS

Three factors combine to give the Epping Forest district its relatively high frequency of thunder. The first is its position in south-east Britain which is, broadly, prone to showers turning thundery on spring and summer afternoons as well as to 'heat' thunderstorms produced locally or imported from the Continent. Secondly, the district lies a few miles north-east of London; prevailing south-westerly winds are often warmed passing over the capital, making the release of any instability more likely. And thirdly, the area includes the Epping Forest ridge, a very modest region of high ground, but clearly able to produce an extra trigger that may turn 'ordinary' showers into thunderstorms, or set off the 'heat' storm.

Thus, thunder is very common on showery days when the wind is from between south and west; on some such days there may be few other reports of

thunder anywhere else in the country. It is also very likely that hot unstable southerlies will give thunder in the area.

Conversely, showery north-westerly, northerly or north-easterly airflows produce thunder much less often, as is also the case with hot, unstable easterlies. One notable exception, however, was the series of heavy storms in a northeasterly on the 20th March 1977, where the ridge seemed to act as the trigger. Normally in such situations, the additional warmth of London is required to turn the showers thundery; on several such occasions developing heavy showers have crossed the area to later turn thundery in west or south London.

SOME 'ODD' THUNDERSTORMS

The oddities of 20th March 1977 and 29th July 1987 have already been referred to. It is often the case that as much can be learnt about thunderstorm forecasting and climatology from the isolated storm as from the widespread outbreaks. Some of the more unexpected or unusual incidents are noted below.

24th February 1977. This late afternoon storm was not particularly heavy in the Epping Forest area, but was a notable one, especially for the time of the year, just to the south in the Stratford area of east London, where there was much thunder and lightning and severe flooding. An old depression was filling up over southern England with its occluded front drifting back slowly south from central England; the area of broken cloud on the depression side of slowly-moving occlusions of this nature is a favoured zone for thunder, in part probably because of the temperature differential between the cloudy and clear zones. February 1977 was most unusual in having six days with thunder heard in parts of Hertfordshire.

Other unusually active winter thunderstorms occurred in the early hours of 13th December 1978 - when a storm with fierce hail, and thunder and lightning every minute for about 30 minutes, passed overhead in a vigorous south-westerly airflow - and early on 8th February 1984. This storm was given a severity coding of 2, the worst winter thunderstorm on the record. It lasted for about 30 minutes, with thunder and lightning averaging about a couple of flashes a minute, and often nearly overhead. There was fierce hail and a near gale. It was associated with a cold front crossing the country from the north-west.

5th October 1984. An old tropical storm moved north-east over northern France, and its occluded front moved north-west into south-east England and East Anglia, where it came virtually to a halt for a few hours. Potential instability was triggered by the relatively warm southern North Sea - and nearly eight hours of thunderstorms were the result in the Epping Forest area.

14th July 1985. A weak cold front was moving south-east towards the area in the afternoon. Just ahead of it, some heavy showers broke out over north London and moved north-east - reaching Loughton just as the front, and its

attendant convergence zone, arrived. The sky went jet-black to the west-north-west, with a crack of thunder to the north five minutes later. Then a 'wall of water' advanced from the west, fanned by a squall and accompanied by a drop in visibility to about 50 metres. This only lasted for about two minutes, but some seven millimetres of rain fell in that time, with 14 millimetres in 20 minutes. Forced uplift over the Epping Forest ridge was undoubtedly a factor in breaking through an inversion and setting off this explosive development, which appears not to have lasted for long after leaving the area.

CONCLUDING REMARKS

This article has summarised fifteen years of thunderstorm records in the Epping Forest district. Although observations show how varied, and sometimes unexpected, thundery outbreaks can be, there is a clear indication that the local topography plays a major part in many of the storms.

South-westerly winds pick up some additional warmth over London, and the air is then forced to rise by the gentle slope of the Epping Forest ridge. These two factors, allied to the frequency of winds from this direction, make the area one of the most thundery in the country.

Some of the records during this period appear through the vigilance of my family and, in particular, local journalist Tony Harvey, to whom grateful thanks are extended.

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EARLY WEATHER OBSERVATIONS IN NORTHERN ENGLAND: PART 2

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Abstract: Bibliographical details and contents summaries are given for 10 sources of information about the weather of northern England during the 18th century. The article has the same layout as that which appeared in part 1 of the series (Tufnell 1987).

INTRODUCTION

The present article is a sequel to one which appeared in volume 12 (number 117) of *The Journal of Meteorology* (Tufnell 1987). It identifies a further 10

sources of eighteenth century weather data from northern England. These are numbered consecutively to the records listed in part 1 and are graded in the same way. Personal diaries again form an important group, but there is also reference to weather observations in parish registers, letters, manuscript and published meteorological texts and in a history book. These records are mostly of the verbal/descriptive kind, though items 14, 15 and 16 have some instrumental weather data. In total, they provide much less information (i.e. around 4500 daily eighteenth century weather observations) than do the sources listed in part 1 (Tufnell 1987). This is because several of them contain just small amounts of weather data and only one (John Murgatroyd's dairy) achieves major significance. It is, nevertheless, vital to list examples of the former, as they may help to fill gaps in the record left by the more detailed sources of weather data.

MAJOR SOURCE

11) *A diary from the Colne Valley* (Huddersfield Public Library): John Murgatroyd (1719-1806) was a teacher and cleric whose name is particularly associated with the Slaithwaite/Lingards area of the Colne Valley (Hulbert 1874, Morehouse 1886) (cf. item 8, Tufnell 1987). In 1986 the surviving volumes of his dairy passed into the care of Huddersfield Public Library. These give details of local and personal matters for the years 1781, 1782, 1786, 1788, 1789, 1790, 1791, 1794, 1796, 1797, 1800, 1802 and 1804. Murgatroyd also left two notebooks, one of which has a few items of weather information. His diary was compiled on a daily basis and rarely omits to mention the weather. This is therefore referred to on almost 3600 occasions during the late 1700s and on more than 1000 days in the early 1800s. Many of these observations are under five words in length, but they can be longer when events merited (e.g. during the severe weather of January 1789). Only a few entries give details of weather impact.

SOURCES OF SECONDARY IMPORTANCE

12) *Richard Viney's diary from near Leeds* (The British Museum): this diary will interest some people because of its observations about contemporary religious figures such as Wesley and Ingham. It also, however, provides weather details for around 250 days in 1744. Nearly 200 of these entries were recorded before the end of July, but after that the diarist became much less interested in the weather. Entries chiefly relate to the Pudsey-Birstall area, near Leeds, though some were made during visits to London, Newcastle and Sheffield. The length of weather observations varies, with the most informative being fairly substantial (e.g. that of 1.2.1744 reads: "The melting of ye Snow continu'd all night and today, as also the thick Air so that one could see nothing of ye Sun nor scarce 100 yds around one all day, and this thickness was accompany'd with a very unpleasant Smell. In ye Evening was a fine Small misty Rain, but not much"). All entries are non-instrumental and only a few mention the impact of a weather event. From remarks made on 2 January and

14 April 1744, it is clear that diaries were also kept in 1743 and 1742. These and perhaps others have unfortunately been lost.

13) *A weather record from Troutbeck* (Cumbria Record Office, Kendal): the archives of the Browne family who lived at Troutbeck in the Lake District (The National Trust 1989) contain about 250 daily, non-instrumental references to the weather. Most of these relate to the first 6 $\frac{3}{4}$ months of 1755 during which time the record is almost complete. Thereafter, except for some observations in August 1755, weather details are very thinly scattered over the period 1776 to 1794. Entries are mostly less than 10 words long and none mention the impact of the weather.

14) *Weather observations for 1767 at Carlisle* (Carlyle 1768): in addition to his rainfall observations (item 5, Tufnell 1987), Dr. G. Carlyle kept a detailed record of the weather at Carlisle throughout 1767. This he published as a table with five columns (Carlyle 1768). The first lists the months of the year, while the second notes the dates and values of the highest and lowest morning and evening barometer readings. A third column follows the same plan for temperature observations. Column 4 gives the day in the month which had the highest rainfall and the amount: it also notes total rainfall for each month. The final column is the most detailed, though individual entries vary from 2 $\frac{3}{4}$ lines in June to around 13 lines for both January and November: it records frost, snow, wind, thunderstorms, etc. In all, specific information about the weather at Carlisle is provided on approaching half the days in 1767.

15) *The history of the county of Cumberland* (Hutchinson 1794-7): despite its title, this two-volume work contains a fair number of weather details, together with notes on impact. In the first two volumes these refer primarily to the 1780s and '90s and include temperature readings made at Brampton, near Carlisle, during parts of 1796. Volume 2 has a distinctly larger amount of weather information and ranges more widely in the periods of the eighteenth century which it covers. Some weather data in these two volumes relate to various months or seasons, but there is also mention of events on particular days (e.g. heavy snow on 10 January 1767). Only a few references are to weather before 1700.

MINOR SOURCES

16) *Thomas Wright's 'Speculum Meteorum'* (Durham University Library): this unpublished manuscript contains a mixture of weather information derived partly from north-east England. It has an almost hourly weather record for 10 March 1783 which was compiled near Byres Green, south of Durham City. There are also detailed weather notes for Hartlepool (12 to 27 July 1773) and Auckland Castle (19 September to 5 November 1773). A further section has weather observations for 13 to 27 July, but does not indicate the year or locality. Evidence, however, suggests that these also are for 1773 and may have been made by Wright himself. The four records include a number of

instrumental observations and give details of the weather on 65 days.

17) *Richard Kay's Bury diary* (Central Library, Manchester): of particular value are the diarist's remarks about medical practices in northern England towards the middle of the eighteenth century (Brockbank and Kay 1959; Brockbank and Kenworthy 1968). However, he also makes over 50 references to the weather. These span the period covered by the diary (i.e. 1737-50) and most relate to events on a specific day. Rain is often noted, especially when it hindered Kay's activities, and there is also mention of frost, snow, drought, and hot, thundery weather. Entries are principally a few words long and non-instrumental, though on 17.12.1748 the diarist interestingly commented: "I never saw the Mercury in our Weather-glass so low before".

18) *Letters of Dean Spencer Cowper* (Hughes 1956): the 30 or so references to weather in these letters vary in length and value. Among the most interesting are those of 1.11.1751 and 27.9.1754. The first mentions early freezing of the River Wear at Durham, while the second describes atmospheric pollution caused by the Swalwell forges and iron works. There is in addition correspondence about the impact of adverse weather (e.g. that of 2.10.1756 on the effects of a 'hurricane'). Most letters containing weather information were written at Durham, but a few refer to events in southern England and one from near Tadcaster gives an account of flooding (letter of 14.12.1747).

19) *The Beetham parish registers of William Hutton* (Cumbria Record Office, Kendal): from 1762 to 1811 William Hutton was vicar at Beetham, a village situated between Kendal and Lancaster. During most of that time his parish registers were used to note events in the local area. On about 25 occasions between 1766 and 1809 they record the weather, giving details of its impact and often specifying the day when an event occurred. These registers are unpublished, but many of their environmental observations (which include references to snow, frost, floods, wind and thunderstorms) have been quoted in an article by the present writer (Tufnell 1983).

20) *Parish registers published by the Yorkshire Archaeological Society* (1899-present): though Hutton's environmental observations are not numerous, their discovery led to the hope that a fair amount of weather data might exist in the many parish registers which have survived. It was therefore decided to examine the 154 volumes so far published by the Parish Register Section of the Yorkshire Archaeological Society (formerly the Yorkshire Parish Register Society). In some cases, locating weather details was greatly assisted by an index to miscellaneous phenomena at the end of a published register, but for many volumes, especially those in the earlier half of the series, there is no such facility. Consequently, these had to be searched page by page, a very lengthy approach which must have caused some weather data to be overlooked. Even so, there can be no doubt that this long set of registers contains only a few weather details. Probably the most valuable are those from before 1650, as other sources of weather information for this period are quite rare. Excluding

some highly generalised and largely worthless comments, the handful of 18th century weather observations in the series can be found in the registers for Marske in Cleveland (10.6.1727) (Wood 1903), Hartshead (14.3.1716-7) (Armytage 1903), Grinton in Swaledale (20.6.1763) (Slingsby 1905), Danby-in-Cleveland (22.4.1754, 29.10.1754) (Collins and Walker 1912), Wintringham (1.2.1714) (Cholmley 1922), Mirfield (1.2.1714-5, 8.10.1767, 10.2.1768, 20.10.1775) (Brigg and Lumb 1923), Thornton-in-Lonsdale (16.3.1719) (Chippindall 1931), Kildwick-in-Craven (18.1.1757) (Livett 1932), Carlton-juxta-Snaith (19-20.11.1729) (Kaye 1934), and Bowes (4.1.1778) (Oliver and Alderson 1964). This list clearly shows that the many volumes published by the Yorkshire Archaeological Society and its predecessor tell us less about eighteenth century weather than do the two registers of William Hutton.

DISCUSSION

Although 20 sources of information have now been described, there is still a long way to go before a continuous and detailed record of eighteenth century weather in northern England has been compiled. Undoubtedly, the material so far identified is nothing like as abundant as, for example, that discovered by Pfister in his research on 18th century weather in Switzerland (Pfister 1985). It would therefore still appear correct to take the pessimistic view, expressed in part 1 of the series (Tufnell 1987), that the aim of uncovering at least 109,500 eighteenth century weather observations from northern England is not going to be achieved. On the other hand, the recent acquisition of John Murgatroyd's diary by Huddersfield Public Library raises the hope that additional major sources will be found. Moreover, even without these, it will still be possible in part 3 of the series to describe another 10 sources of eighteenth century weather data from northern England.

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MAJOR DEVELOPMENTS IN CROP-CIRCLE RESEARCH IN 1990: PART 3

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Abstract. This article completes a brief report on the 1990 circles season as compiled by the CERES Organisation. The first part of the report with complete abstract was published in this journal in February 1991 and the second part in April. The present section includes preliminary theoretical reasonings and some analytical work about the vortex-line systems of 1990. Further details with illustrations and additional articles from other CERES investigators is given in the new book *Circles from the Sky* published by Souvenir Press in June 1991.

SOME THEORETICAL CONSEQUENCES

The 1990 season was outstanding with its great variety of wholly unexpected natural vortex-circle types and groups. Moreover further unimpeachable evidence was forthcoming in the form of eye-witness sightings (as discussed in *Circles from the Sky*, Souvenir Press 1991). This has helped to confirm that, aside from a low number of obviously-faked circles, the evidence is overwhelming in favour of a natural atmospheric origin for the circles effect, and it is certainly the case that all truly open-minded, unbiassed people who have properly studied the facts accept that this is so.

Indeed, the proof is overwhelming that the circles are the result of locally

gale-strength or hurricane-strength winds spinning as partially-ionised vortices (recall that conventional whirlwinds are ionised too) - and occasionally these circle-making vortices produce sound and light at the same time. We fully expect that considerable theoretical advances will ensue in the coming years as the analyses proceed, especially for the more extraordinary groups such as the much-publicised Alton Barnes circles. This type displays interesting aberrations from circularity which positively help the generalised vortex theory. For instance, it has been suspected for some time that vortices can have complicated but symmetrical internal structures which upon impact with the crop and ground lead to the well-known quintuplet formations or the broad multi-ringed systems, but at Alton Barnes crop and ground impact of *unstable* vortices gave rise to less regular patterns and exposed for analysis something of the satellite - forming and ring-forming elements in a 'miscarriage' situation. By studying imperfect cases like these we are learning more quickly than expected the working details of the complex vortices, and are also demonstrating how effective a research tool the study of imperfect circles can be.

In this context one further circle requires special mention because although it was only a single circle it had the unusual characteristic of being a circle of the 'radially-inward suction' kind. This, the first 'truly radial inward' circle in our records of circles (which by April 1991 totalled 1750), happened at Braishford, Hampshire in August. The five-metre circle was characterised by a ring of bare earth created by an inward parting of the wheat whose heads all lay "towards the centre as though it had been combed".

This directional motion produced a conical centre of unflattened wheat protruding upwards from the bed (*Romsey Advertiser*). The circle therefore demonstrated the whirlwind phenomenon of vortical spin-up, in the manner already explained by John Snow in *Circles from the Sky*. At the same time a considerable theoretical advance was made by Dr. Tokio Kikuchi who recently performed computer-simulated modelling of the impact of a spiral vortex (or nanoburst) with a plane horizontal surface, and discovered that the rotational flow at the point of impact rapidly leads to the appearance of a counter-rotating ring, as occasionally seen naturally. This important discovery is being announced at the Twentieth General Assembly of the International Union of Geodesy and Geophysics in Vienna, Austria this August under the title "Nanoburst: Microburst by a spiral vortex of micrometeorological scale".

Strange Attractors. Whereas prior to 1990 due caution demanded the conclusion that there was then insufficient evidence to make statements about the possibility of circle-system alignments with tractor lines, enough additional data emerged in 1990 to permit such an announcement. In fact, a surprisingly large fraction of the linear circle-sets (spurred singles, dumb-bells, triple sets, and Alton-Barnes type extended complexes) were found aligned parallel or perpendicular to tram lines. A few were centred precisely along tramlines, and some others were angled at 45 or 60 degrees to tramlines (while others, to be sure, were not).

Analysis is incomplete but one can already say that it appears that a degree of

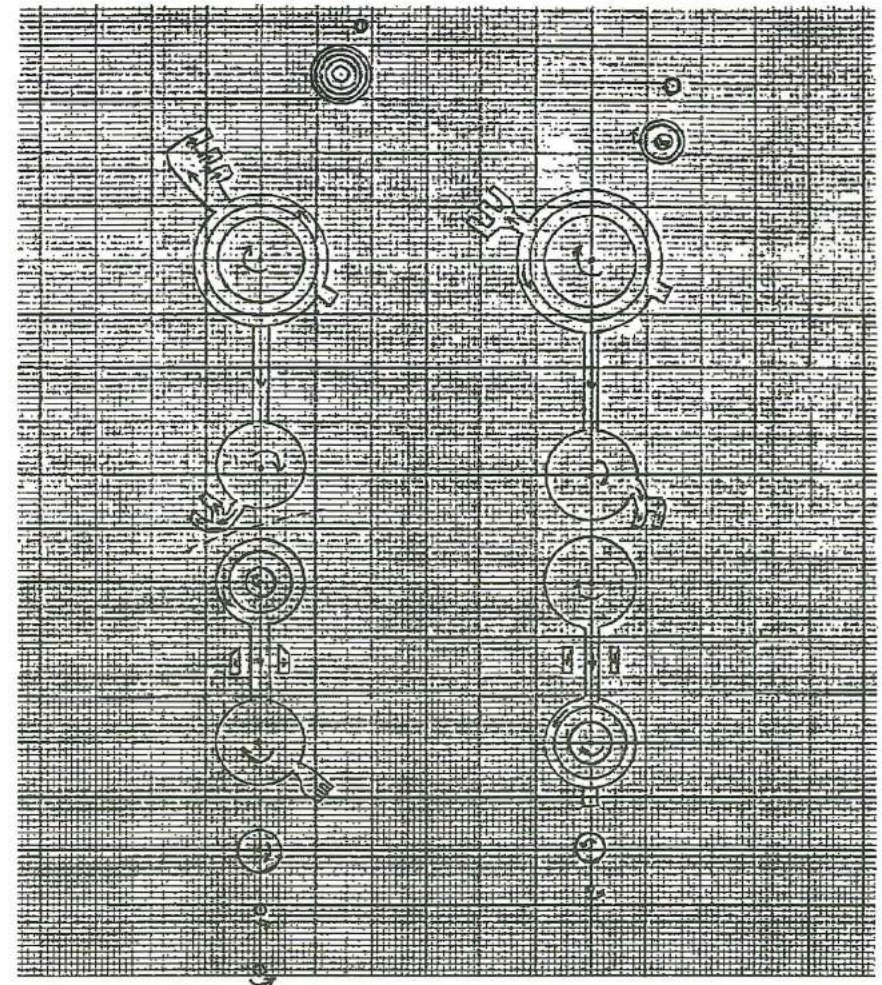


Figure 8: Approximate scale drawings of the principal Alton Barnes circles (left) and the Stanton St Bernard circles (right) arranged on a square grid using a nine-metre mesh. The Stanton circles were aligned along tractor lines but the centres of the Alton circles, although parallel to tractor lines, were offset by about five metres to the left. The centres of the five biggest Stanton circles fall upon 9-metre grid points within accuracy limits of ± 0.75 metre.

circle alignment with some sort of inherent, largely-veiled but regularly-spaced *grid system* can occur (Figure 8). The right-hand drawing is an approximate scale drawing of the six circles in the Stanton St. Bernard complex which form the *linear part* of the chain. The smallest circle is 'out of step' being centred 6.5 metres from the next, but after that the next five centres give centre-to-centre distances of respectively 17.4, 27.2, 18.3 and 36.6 metres which correlate well

with points on a *nine-metre network* or a semi 18-metre network.

For Alton Barnes the correspondence is almost as impressive. From bottom to top the first four inter-centre distances give 10.0, 18.4 and 27 metres, a reasonable start for a basic nine-metre grid (or semi 18-metre grid), but then comes a non-'integral' spacing at around 21 metres, followed by a quasi-nine multiple at 35 metres. For the purpose of the drawing, instead of deforming the grid at this point we have, for convenience, reduced the non-integral spacing of 21 metres to 19 metres to allow for this single irregular offset. I should point out that a distance of 17-17.5 metres commonly corresponds to the spacing *between* adjacent pairs of tractor marks, and this leads to an overall network-repetition length close to 18.5 to 19 metres when adding on the paired tractor-line widths themselves (the tractor's width of about 1.6 metres creates pairs of lines which are often around 1.6 to 1.8 metres across). Wider spacings of 21-23 metres arise from the use of longer boom lengths. On some farms the spacing was 18 metres for many years and then a switch to longer booms was made.

The overall centre-to-centre length of the *principal* five circles at Stanton was 99 metres compared with 101 metres for the Alton set. It should be recalled that the two circle sets were located three kilometres apart and were angled in quite different directions with regard to the magnetic meridian (098 and 346 deg respectively). Despite this, the circle complexes have remarkable similarities as noted here, and others besides. The clawed fins for instance egress primarily at around 30, 45 or 60 degrees to the main axes (which may suggest they aimed at various points on the inferred grid system). Also there are four circles or rings in each set, eight in all, each having a diameter close to 15 metres. This tends to suggest the existence of a preferred diametral size related perhaps to a well-defined Larmor radius, the consequence of the magnetron effect (the spiralling of high-velocity charged particles in the direction of an external magnetic field). The suggestion that preferred circle sizes exist seems supported by the observation that so many of the big circle diameters and ring diameters found in 1989 and 1990 were clustered about diameters of 31, 62 and 93 metres. In earlier years I had noticed a slight tendency for circle-diameters to occur at 4, 8 and 15 metres.

It would seem that the proposed *grid* (which sometimes corresponds to the visible tramlines) could act as a *guide for the local orientation of a vortex line or sheet*. This would further intimate that electrical effects play a major role in this singular correlation. I propose that the primary vortex if electrified - as indeed I have inferred it to be for other reasons anyway - sometimes finds itself attracted to tractor-line regions because of local electric field anomalies initiated by the repeated passage of tractors up and down the field. Tractors of the same axle width return to the same fields year after year. They begin by working parallel to field boundaries, as a result of which the boom lengths of the planting, pesticide and fertilising machines assure, in some field systems at least, a repetition of the tractorways up and down the field. Where ploughing and planting is done at right angles in alternating years a species of square-based grid could result. To this novel phenomenon - the electric-field anomaly

link with tramlines - I have given the name *strange attractor* (*J. Meteorology*, vol. 15, 317 - 320, 1990) a name chosen via its use in chaos theory by which a degree of order seems to appear under somewhat unexpected circumstances.

Reasons for the development of electric-field anomalies, if that is what they are, have yet to be evaluated. I suggest that one is that the repeated passage of heavy farm equipment leads to compaction of the thin chalk-dust laden soil to depths approaching the bedrock. This would affect the flow of sub-surface water and hence modify the electrical conductivity of the dry chalky soil and therefore the local geo-electrical field. Such effects would be worse in the prolonged dry conditions of the hot summers of 1989 and 1990. Another possibility is that effects arise from sub-surface electric currents induced by corresponding currents in the upper atmosphere. These effects would be more important at peak times of the eleven-year sun-spot cycle, as pointed out by George Nehls (see below and in *Circles from the Sky*). 1990 was a year with unusually intense sun-spot activity and for some months since 1989 there have been spectacular outbreaks of the aurora borealis as a result. While the Earth's upper-atmosphere activity is likely to be less strong in 1991, the circles effects in the crops might be nearly as bad if the summer is again dry. On the other hand, a very wet summer might arrive at dampening out the strongest of the anomalous circles effects observed in 1990. In Australia this spring scientists were monitoring an amazingly strong and persistent sub-surface electrical current which traversed the continent between the chief basaltic plates for a distance of some 5600 kilometres! It may be the same in certain zones in the Northern Hemisphere.

The foregoing argument concerning the use and effect of tractors may help to explain why the circles effect in its advanced form, i.e. as evidenced by recent complex-circle discoveries, is a modern development in what is otherwise an age-old problem. Plain circles and simple ringed circles date back to the early agricultural era; the complex circle sets could be a recent manifestation related to farm-machinery usage in the field, especially over the shallow, dry chalky soils, combined with changes in agricultural practise. The latter embrace the uniformity of seed production and the evenness of crop height which results from identical stem-lengths, seed-planting in neat rows by today's well-designed agricultural machines, a level spread of fertilisers, and a lack of spurious weeds. These factors help make for a uniform field growth in which it is easier to detect small circles, narrow rings, narrow spurs, etc, than ever before. From the time of the Napoleonic wars until the Second World War much of Wessex was down to sheep farming. Cereal fields did exist but they were much smaller than today's fields. Only in the last fifty years has 'prairie' farming of cereal crops become widespread. Centuries and millennia ago the seeds were broadcast unevenly by hand, the manure scattered likewise. Until fifty years ago horses were pulling the plough in many areas. Now the tractors are heavier than ever before, and so is the farm machinery, especially the combine harvesters which follow the same tracks made by the tractors and compact the subsoil so thoroughly. Maybe more complex circle systems appear

as a result, and this is what leads some people (notably the alien-intelligence brigade) to speak of an 'evolution' in crop-circle complexity as though it was caused by paranormal happenings. We certainly accept that it is possible that some relationship with the eleven-year sunspot cycle may exist. George Nehls of Minnesota has mentioned that the frequency of power breakdowns in some areas may relate to an increased ionisation in the atmosphere from this cause. I have written at length about the natural ionisation of vortices and the way they could link with electric field anomalies, Gordon Garrould has discussed ionisation levels in crops from various causes (*J. Meteorology*, vol. 14, November 1990), and Professor Hiroshi Kikuchi has written theoretically on naturally-formed dusty plasma vortices as a possible origin of crop circles (EHD Vortex in the Atmosphere with Helical Turbulence in Electric and Space-Charge Fields). This may all suggest that the number and complexity of crop circles may have peaked with the maximum in the sun-spot cycle which happened late in 1990, or the peak may come in 1991 before it tails off again. The crucial factor in the end may be the character of the season's weather as explained above. It seems that the present sunspot cycle has been unusually strong, while the one which peaked in 1980-81 was weak. In returning still further into the past (by looking at the cycle maxima of 1970, 1959, 1948 etc) one moves progressively towards quite a different farming regime, as explained before - one which was very much less developed from what it is now.

Needless to say there are people who continue to close their minds to explanations that could be so rational - chiefly because rationality equates with the scientific - and they prefer to bang their empty drums in support of their groundless fairy-tale beliefs. Of course they have never produced any proof to support their wishful thinking. Their ideas are what dreams are made of, and this leads them to be carefree and reckless when it comes to observation and reporting - blindly ignoring, as well, the extensive eyewitness evidence of spinning winds forming circles.

The chalk hills of Wessex are the home of the circles phenomenon, just as in the Neolithic and Bronze Age they were the home of the sacred stone rings, timber rings and circular round-barrows. Our ancestors found simple circles and rings in their crops and in the grass, and they worshiped them. The results of the author's study into this fascinating facet of circles research, begun in 1980, and put in writing from 1983 onwards is set out in considerable details in two books published elsewhere this year. The first of these, entitled *The Goddess of the Stones*, is published this June by Souvenir Press, London. This work establishes without doubt very extensive proof that the circles effect has always happened, and always will as long as there is suitable vegetation to display it or witnesses near enough to see it.

THE WORK CONTINUES

1991 has begun well. Professor Christopher Church (Miami University) has modelled the Cheesefoot Hill region and set it up in a wind-tunnel using smoke streamers to demonstrate the windflows. Dr. Tokio Kikuchi (Kochi University)

has pursued his theoretical calculations and proved by computer-simulation that upon impacting a horizontal plane spiralling vortices create circles with outer rings. Sheldon Wernikoff (CERES) has photographed quintuplet circles forming as a result of plasma vortices impacting an anode in an ionised gas. And Professor Y. H. Ohtsuki (Waseda University) has confirmed by direct experiment that when plasma vortices impact a charged, powder-covered, metal plate circles with concentric rings are produced!

Acknowledgements. We wish to thank the very considerable number of people - including all those named in this report and in *Circles from the Sky* - who by their participation as part of the international CERES operation, or in collaboration with CERES, made possible this important collection of detailed scientific data on the circles effect.

LETTERS TO THE EDITOR

SQUALLS IN NOTTINGHAMSHIRE 25 DECEMBER 1990

After reading about the Trowbridge tornado of Christmas Day 1990 (*J. Meteorology*, February 1991 issue), I must mention the events that happened here in South Nottinghamshire that morning. I was in Ruddington, five kilometres W.N.W. of Keyworth. The wind soon rose to gale force, recorded as S.S.W. 30 knots at 0900 at Keyworth with a temperature of 8°C. The wind increased further and by 1015 G.M.T. there was driving torrential rain. Some minor damage occurred to slates and branches.

The sky then darkened to the west and a spectacular fast-moving roll cloud advanced towards us. There was a brilliant flash and a clap of thunder as the squall arrived with hail, and then heavy sleet. The wind swung round to west 44 knots (estimated). Suddenly, there was a furious gust of wind causing solid six-foot high wooden gates to crash into the street. The sky was in turmoil with further forks of lightning, and large snowflakes could be seen a few hundred feet up. The sleet and hail squall peaked at 1038. The temperature had fallen to 3.5°C. The sky then cleared, the wind fell light and by noon it was a fine winter's day. I am convinced that there had been some sort of tornado-like disturbance. On receiving my monthly Metform the Meteorological Office rang me to seek details as other suspect tornadoes and dramatic squalls had been reported from the Midlands.

Keyworth, Nottingham, U.K.

JEREMY HODGSON

LIGHTNING IN ASTRONOMY

The idea that many violent events in astronomy are caused by electrical processes similar to terrestrial lightning, but on a vastly greater scale, led Dr. C. E. R. Bruce (1902 - 1979) to devote much of his working life to develop this idea. Many of his papers on terrestrial and cosmic lightning were published in scientific and technical journals but astronomers have been slow to realise the significance of his theory of cosmic electrical discharges.

I have therefore produced a booklet describing Bruce's work in astronomy, which contains a popular account originally published as a chapter in *Penguin Science Survey 1968*, with added biography and notes of later developments, which may also be of interest to meteorologists. The booklet (*Electrical Charging and Discharging in Astronomy*: 150 x 210 mm, 39pp) is available from the author at the address below, price £3.00 post paid in the U.K. Add £1.00 for overseas.

26 St. David's Drive, Broxbourne,
Herts, EN10 7LS, U.K.

ERIC CREW

WORLD WEATHER DISASTERS: OCTOBER 1990

- 1: M. tug *Barbara Lyn* sank in storm on Lake Huron, 19 km off Huron City, Michigan, U.S.A., leaving one crewman dead. *Lloyds List*.
- 2-6: Tropical storm "Ira" hit Vietnam and Thailand, brief details below:-
 VIETNAM: provinces of Dong Nai, Nghe Tinh and Thai Binh worst hit, up to 483mm of rain fell in some areas, causing widespread flooding, heavy crop and property losses reported, nine deaths reported.
 THAILAND: serious flooding in 19 provinces, more than 120,000 families affected by floods which swept away 49 bridges, more than 500,000 acres of crops under water, eleven people reported dead. *L.L.*
- 3-5: Storms and floods associated with hurricane 'Klaus' hit islands of Martinique, St. Lucia, Antigua and Trinidad; on the island of Martinique, which was worst hit, five people died, three others were missing and 1500 homes were destroyed. One person died in floods on Trinidad and 13 were injured on St. Lucia, in the 24 hour period up to 0800 hours on the 4th 72.2mm of rain fell on St. Lucia and in the 24 hour period up to 0800 hours on the 5th 73.9mm fell, banana crops damaged. *L.L., International Herald Tribune*.
- 3 (reported): Lake Eyre in South Australia has begun to fill for the fourth time this century - and the second successive year. *Daily Telegraph*.
- 4-6: Heavy rains in association with tropical storm "Rachel" hit provinces of Nuevo Leon, Coahuila and Durango, northern Mexico, left 18 dead, seven missing, all near the city of Saltillo where floods up to 1.5 metres deep reported, many thousands of people made homeless, serious crop and property damage reported. *L.L.*
- 5: Cessna 172 aircraft crashed at Bua, Fiji islands after flying into a whirlwind, no injuries to three aboard. *L.L.*
- 6: Strong winds in southern England, in the Solent man died after falling overboard from yacht. Heavy rain and high winds flooded roads in Derbyshire and brought down trees in same county and in Leicestershire. High winds and rain caused floods and landslides in Scotland, 200 people evacuated from homes on south side of Glasgow. *Daily Telegraph*.
- 6-8: Typhoon "Hattie" hit Okinawan island chain on the 6th with winds gusting to 169 km/h causing disruption to airlights; the storm, downgraded to a tropical cyclone, hit Japanese islands of Kyushu, Shikoku and Honshu with winds of 108 km/h and heavy rains on the 7th/8th. Heavy rains touched off landslide in northern Shikoku which left three dead and 14 injured in bus hit by landslide. *L.L.*
- 7-8: Cyclone in Bay of Bengal, heavy seas swamped fishing fleets, at least 70 fishermen drowned and 25 vessels and more than 300 crew remained unaccounted for; the offshore islands of Hatia, Sandwip, Kutubdia and Urir Char also hit by storm; about 20,000 people made homeless, when islands submerged under 1.8 metres of water for about six hours; the

- storm had winds gusting to 113 km/h, thousands of hectares of crops flooded near Chittagong. *L.L.*
- 11-13: Tropical storm "Marco" hit Florida, Georgia, South Carolina and North Carolina, U.S.A., insured property losses amounted to \$15 million, winds gusted to 105 km/h in Florida, where power lines were brought down and buildings were damaged. Floods in Georgia on the 12th left four people dead and damage put at \$34 million, 450 people made homeless by floods in state, in the Carolinas six deaths reported, four died when dam collapsed, the other two died in traffic accidents. *L.L.*
 - 13-14: Heavy rains caused floods in Gilan province, Iran, left six people dead, destroyed some 300 homes and caused heavy damage to road and bridges. *L.L.*
 - 14: Heavy rains touched off flash floods and landslips in Blumenau, Santa Caterina province, Brazil, leaving 17 dead and injured 35, about 30 homes destroyed and some 2000 people made homeless; the storm lasted from 0300 to 0500 hours and only affected certain areas of city. *L.L.*
 - 14: Flash flood drowned three students picknicking at waterfall 24 km south of Padang, West Sumatra, Indonesia, one other student missing. *Jakarta Post*.
 - 17: Torrential rains and floods in southern France, about 150mm of rain fell in less than an hour in parts of the Var region near Toulon and 100mm fell in the Alpes-Maritimes region; floods up to two metres deep on roads outside Frejus, hundreds of homes damaged and one person drowned when car swept off road. *L.L., I.H.T.*
 - 18: Tropical storm "Lola" hit six provinces in central Vietnam destroying or damaging 110000 homes and leaving seven people dead, damage and casualties caused by heavy floods brought on by heavy rains, in Thua Thien-Hue province average rainfall varied between 300mm and 700mm. *L.L.*
 - 18-19: Heavy storms, high winds and tornadoes hit eastern seaboard states of the U.S.A., about 50 people injured; one tornado hit Reisterstown, a Baltimore, Maryland, suburb, some buildings badly damaged. *I.H.T.*
 - 23: Strong thunderstorm winds hit two villages in Boyolali, central Java, Indonesia, 81 homes destroyed, with another 250 damaged, many trees uprooted, the storm, which left three dead and 45 injured, struck about 4.00 p.m. (local time) and lasted about half an hour. *J.P.*
 - 27-28: Heavy rains and flooding in areas of Northern Ireland and southern England; near Ballycastle, Co. Antrim, a farmer swept away and drowned in floods; in southern England 13 rain-related deaths in road accidents, parts of Canterbury, Kent under 0.6 metres of water. *B.E.M., D.T., I.H.T.*
 - 31 (reported): Two boy scouts whose hiking team was surprised by a bad Alpine storm died in hospital at Grenoble from the effects of exposure. *B.E.M.*

ALBERT J. THOMAS

LITERATURE REVIEWS AND LISTINGS

Book Reviews

WEATHER SATELLITES: SYSTEMS, DATA, AND ENVIRONMENTAL APPLICATIONS. Edited by P. Krishna Rao and others. American Meteorological Society (45 Beacon Street, Boston, MA 02108-3693), 1990, xiii + 503pp, 85 US \$.

State-of-the-art books, which examine their subject in a comprehensive and up-to-date fashion, are always welcome. That this is such a book can be readily deduced from its carefully-worded title, its many editors and contributors, its numerous references and its stated aim of providing "students and practitioners of atmospheric sciences with a comprehensive overview of the field". As a result, it avoids the imbalance which pervades the literature about satellite meteorology due to a concentration on environmental applications at the expense of technical matters. Indeed, the latter are given detailed consideration in the first 200 pages of the book. This leaves most of the remaining 300 pages for a discussion of satellite applications (to meteorology, land and ocean sciences, climate, and agriculture, with a concluding section on future satellite systems and applications). A summary prefacing each of the 11 sections, together with a glossary and a very necessary list of acronyms and abbreviations, help in the reading of the book. Furthermore, as explained in the preface, the text which has finally appeared is a much condensed version of the original material received from contributors. This thankfully means that the reader is not subjected to a mass of unessential verbiage, though it still leaves a wealth of detail to be absorbed. The fact that the book has an American bias should not provoke criticism, as this faithfully reflects the key role of Americans in developing weather satellites. In any case, the work of other nationals is adequately mentioned - there are, for example, chapters on the European Meteosat and Japanese GMS programmes. This, then, is a book which can be wholeheartedly recommended, for it is probably the best in its field. Teachers, students and practitioners of the subject will all find that it contains much of value.

EXTRATROPICAL CYCLONES: THE ERIK PALMÉN MEMORIAL VOLUME. Edited by C. Newton and E. O. Holopainen. American Meteorological Society (1990), 262pp, 63 US \$.

This volume is a tribute to the great work in the field of meteorology of Erik Palmén and covers twelve papers presented at the Palmén Memorial Symposium on Extratropical Cyclones in Helsinki in 1988. As such, it reflects current thinking in the field of extratropical cyclone research and gives an invaluable insight into the history of developing thought on the subject. The first three chapters indicate how research has developed thanks to the work of Palmén. His role in the development of cyclone concepts is discussed in impressive detail by Newton in Chapter 1, enhanced by a study of General Circulation work in the 1940s and 1950s by Riehl in Chapter 2. The remaining

chapters bring us up to date and this historical perspective makes the book invaluable to academics and students alike. Perhaps hard going at some points, it would certainly aid the teaching and learning of cyclogenesis theory. Later chapters concentrate on the Theory of Extratropical Cyclones, processes contributing to their rapid development, Orographic Cyclogenesis and a consideration of the organisation of cloud and precipitation. Fronts, Jet Streams and the Tropopause are also investigated. This must surely be a book which will eclipse most others on this topic. The final two chapters give a fascinating account of work aimed at prediction, surely the practical purpose of meteorology. The importance of observations to improve numerical prediction is clear. The editors comment that Palmén was a "world citizen" and his importance to meteorology is immense. This book is a fitting tribute to a genius.

ANTONY CLAY

TORRO TORNADO DIVISION REPORT: August and September 1990

August 1990 was mostly warm, sunny and dry, particularly over England, where it was one of the hottest Augusts in the Central England record from 1659. Not surprisingly there were a number of reports of land devils, six in all, mainly during the heatwave at the start of the month. There was also one tornado, and two reports of funnel clouds. *September* was rather warm and anticyclonic up to about 17th, then cooler and more unsettled. Three eddy whirlwinds were reported from Scotland and the Lake District, and there were land devils in Northumberland on 10th.

LD1990August3/I. *Wallingford, Oxfordshire (SU 6089)*

Miss Florence Boughton observed a land devil at about 1200 GMT. A piece of netting was lifted above roof-top level. At 1200 Britain was covered by a ridge extending from a high of 1031mbar in mid Atlantic to another of 1030mbar near the Polish coast. In many parts of England it was one of the hottest days on record, with 35°C widely in the Midlands and south-east.

LD1990August3/II. *Hucclecote, Gloucestershire (SO 866180)*

A "mini-whirlwind" hit Insley Gardens, Hucclecote, on the eastern side of Gloucester, at about 1430 GMT, bending trees and slamming doors (*The Citizen*, 4th August, sent by Mr. D. Brooks). A new British record temperature of 37.1°C was established at Cheltenham in the same county during the afternoon.

LD1990August4/I. *Glenridding, Cumbria (NY 378169)*

This land devil picked up a large caravan and dropped it on the caravan next to it. The weather was hot and sunny, with little if any breeze (information from Ms. Paula Robinson, forwarded to TORRO by Bob Prichard). Pressure was still high in the south, but a weak cold front lay across the Midlands at 1200, and maxima in Cumbria were only 17-20°C, which makes one wonder whether the

reported land devil is correct.

LD1990August4/II. *Ibstock, Leicestershire (SK 4010)*

A land devil tore through a garden at Ibstock, flattening flowers and ripping off a greenhouse roof (*Mail on Sunday*, 5th August). Maxima in the Midlands were around 25-28°C, with about 12 hours sunshine.

LD1990August8. *Fox Hills, Ash Vale, Surrey (SU 914529)*

Mr. Chris Hall, who observed this land devil with Mr. Robert Smith, prepared an excellent, detailed report on it. The land devil appeared as "a swirling column of black dust/ashes" about 7-8 feet (two metres) high, moving erratically from north-west to south-east 'with an audible swishing sound'. It passed out of sight after being watched for about two minutes. The location was a large tract of undulating, sandy heathland which had been burnt two or three days previously. The weather at the time (about 1630 GMT) was sunny and warm, with a light breeze, force 2-3. At 1800 a high, 1030mbar, was centred to the south-west of Britain, with a gentle westerly airflow over southern districts. Surrey had prolonged sunshine with maxima around 26°C.

TN1990August 9. *Near Mid Ardlaw, Grampian (NJ 9463)*

Mrs. Bessie Furness and her husband were on a coach holiday when they saw a funnel cloud near Fraserburgh at about 1330 GMT. It appeared to reach the ground twice, possibly near Mid Ardlaw, and was visible for at least 15 minutes. Afterwards there was very heavy rain. Mrs. Pat Sutherland and her husband saw the funnel cloud from the same road (the A98), and probably in almost the same place; they passed directly underneath it. "It was raining torrentially before and after, but when we passed under the funnel the rain was less heavy and I had a clear view of it. To me it looked like a twisted veil of gauze hanging in the sky obliquely, tailing off to a slender point, not reaching the ground, the point about 200 feet above us. We could see it writhing and spiralling clearly". Both sets of witnesses had to drive slowly because of the very heavy rain; in Fraserburgh it was described by Mrs. Sutherland as "the heaviest rain I have ever witnessed in this country"; there was also thunder and lightning. Mrs. Sutherland said that waterspouts were seen over Fraserburgh Bay (NK 0066) and off Sandhaven (NJ 9667), and a funnel cloud from the Technical College in Fraserburgh (NJ 9866). Most of these may well be sightings of the same funnel. At 1200 north-east Scotland was in a trough behind a frontal system over the North Sea. There were also slight signs of a trough at 500 mbar. Scotland had showers, and Kinloss, Grampian, was the wettest *Daily Weather Summary* station on 9th with 12.3mm.

LD1990August23. *Sandwell Valley, West Midlands (SP 017917)*

A land devil, at 1410 GMT, lifted paper, straw and leaves "in a vortex fashion" to a height of about 40 feet (12 metres). It moved away quickly in a N.N.E. direction (*COL*, August 1990, p.14). At 1200 England was under the influence of a high, 1029mbar, centred off the North Sea coast of Germany.

FC1990August25. *Barton-le-Clay, Bedfordshire (TL 0830)*

At 1815 GMT Mr. Ian Kelly noticed "a black finger of cloud extending downwards" from a cumulonimbus to the north-east, which was producing frequent lightning. The "finger" was about 5-10² long and about a mile (two kilometres) away. It persisted for about one minute; no rotation was visible. A small front crossed England on this date within a very flat pressure field. There were thunderstorms in some areas, with heavy falls of rain, especially in East Anglia and Kent (*COL*, August 1990, p.3).

2FC1990August30. *Guernsey, Channel Islands*

Two funnel clouds were observed from Guernsey Airport in the afternoon (*COL*, August 1990, p.15). A broadly westerly airstream covered the area, with a low, 992mbar, off north-west Scotland at 1800. At 500mbar the axis of a trough lay over the Channel Islands. Guernsey was sunny, with a trace of rain between 09 and 21 GMT.

LD1990September10. *South Newsham, Northumberland (NZ 3078)*

In *The Journal* (Newcastle upon Tyne) of 14th September reporter Tony Jones gives a detailed account of two whirlwinds seen on the previous Monday morning by Anne and George Rix. Mrs. Rix first saw "a circle of straw about 12 to 14 feet in diameter and about 15 to 20 feet of the ground, flying around in a stationary position in a perfect circle. After a few seconds it disintegrated, and as we stood and stared a sharp breeze blew up, accompanied by a low hum". Almost immediately the phenomenon was repeated a few metres away. Mr. Jones consulted meteorologists Suzanne Charlton and Philip Eden, who both identified the whirlwinds as land devils. At 0600 most of the country was within the central isobar of a high, 1031mbar, over central Ireland. North-east England had a dry day with sunny periods and maxima of 17-19°C.

EW1990September14. *Near Fairfield, Cumbria (NY 3612)*

Mr. Peter Matthews observed several whirlwinds on the col between Fairfield and St. Sunday Crag in the Lake District. "The wind came periodically in very strong dust whirls . . . The wind was so strong in these eddies that it roared like the propeller on a light aircraft and was very impressive . . . the wind was being funnelled up the valley . . . convectively and as soon as it hit the saddle point between the two peaks it produced a very strong dust whirl" about two metres across. The time was about 1300 GMT. It was a warm afternoon, with little wind on the summits. At 1200 the area was in a light north-westerly airstream around a high (1035mbar) to the north-west of Ireland.

EW1990September28. *Near The Cairnwell, Grampian (NO 139781)*

Mr. H. Adamson was driving along the A93 from Braemar to Blairgowrie and approaching the Glen Shee Chairlift when "a small whirl, of what at first appeared to be smoke" appeared about 50 metres away in the car park. "Suddenly the cloud increased in size and velocity, travelled the intervening distance in approximately two seconds and engulfed the car. The windscreen and headlamps were shattered and the bodywork so damaged by pitting that a

complete respray was necessary. The dust cloud was estimated to be five metres wide at the base, ten metres at the top and 15 metres in height. The composition of the cloud ranged from fine sand to pebbles approximately 20mm in diameter". Scotland was covered by a W.S.W. airstream at 1200, with a frontal wave off the north coast. The airflow at 500mbar was similar. Eastern Scotland was mostly cloudy, with light rain in places.

EW1990September. *Grisedale, Cumbria (NY 3715)*

Ms. Paula Robinson saw a small whirlwind in Grisedale. The weather was wet and windy.

Additions to previous reports

TN1983winter. *Near Boubly, Cleveland (NZ 768189)*

This tornado, described as having a "classic" shape, picked up sand and water from the beach, moving slowly from west to east. It was a breezy, overcast day (Mr. Peter Lamprey).

FC1988August. *Arnol, Lewis, Western Isles (NB 3148)*

Mr. John Cunningham photographed a funnel cloud over the village of Arnol on the north-west coast of the Isle of Lewis in early August 1988.

Waterspouts worldwide

FC1990July 25. 32°03'N., 126°34'E. Ship *Graiglas*, observers R. Wade, R. Sullivan.

WS1990August12. 01°13.5'N., 103°46.8'E. *Arma*, R. Sarda and others.

WS1990August29. 36°19'N., 18°04'E. *Liverpool Star*, observer not stated.

WS1990September14. 08°31'N., 71°22'E. *Benavon*, P. Brooks and others.

WS1990September28. 13°44.7'N., 112°02'(E?). *Benalder*, I. A. Marshall and others.

WS1990September30. 32°53'N., 19°13'W. *Charles Darwin*, observer not stated.

TORRO THUNDERSTORM REPORT: October 1990

By KEITH O. MORTIMORE,

*Thunderstorm Division, Tornado and Storm Research Organisation,
77 Dickets Road, Corsham, Wiltshire, SN13 9JS*

After a particularly thunder-free July-September period with thunder-day totals 28 days below the normal, activity returned to more normal values in October. Thunder was heard somewhere in the U.K. and Ireland on 16 days, exceeding the October normal by three days, but with near normal totals over Scotland and Ireland the overall total was the result of increased activity over England and Wales. The south-eastern counties of England were very thundery and coastal areas from the Isle-of-Wight to Kent were subjected to an unusually high number of days with storms of a severity and duration not normally encountered in October, due quite significantly to the abnormally high sea temperature in the English Channel. A similar situation prevailed around the coasts of south-west England and south Wales. Most parts of West and East

Sussex reported thunder on five days with six in places, especially over the Downs. Three or four days were widespread over other south-eastern counties and two to four days were also widely reported in the west country, south Wales and in the north Midlands but elsewhere activity was much less widespread.

Thunder-days in October 1990 were as follows: (averages refer to the period 1951-80)

	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	Tot	Ave	
England		X													X	X	X	X	X					X	X	X	X	X	X	X	X	14	10	
Wales		X													X			X					X	X				X	X	X			8	5
Scotland														X	X	X	X										X						5	6
Ireland													X	X	X											X	X		X	X			7	6
Total		X											X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	16	13	
Netherlands		X																X									X	X	X	X	X		7	8
Belgium		X	X														X	X												X	X		6	

Following early cold frontal rain the 3rd was a showery day and hail fell widely. In the afternoon there was a report of thunder in the Swansea area of south Wales and in the evening a thundery shower developed over Skiddaw, the dominating mountain overlooking the town of Keswick in the Lake District. It was the 13th and 14th before thunder was heard again, affecting the western and northern seaboard of Ireland and Scotland on both days. Southerly wind carried a few thunderstorms northwards across the west country and Wales during morning of 15th and in the afternoon and evening further thunderstorms tracked north-eastwards from the warm continent across south-eastern counties of England. There were also isolated thundery outbreaks in Ireland and the Northern Isles of Scotland.

Thunderstorms in the south-east were quite active with some heavy falls of rain which resulted in local flooding. Eastbourne town centre was badly flooded and some motorists had to abandon their vehicles in nearly one metre of water. A number of houses were also inundated. The storms were also electrically very active and at Thundersley (Essex) 160 flashes of lightning were counted in 25 minutes. Power supplies were cut in a number of places and in addition squally winds accompanied some of the storms. During the early hours of 16th thunder accompanied heavy rain in the Isle of Man, north-east England and in parts of Scotland. On 17th a warm-front thunderstorm occurred in south-west Scotland in the early afternoon and a few thundery outbreaks accompanied a cold front as it pushed northwards into southern England, while in the evening a few storms moved north-westwards into some eastern counties from a frontal wave over the North Sea.

Lightning was responsible for power failures in the Wheatley and Waterstock areas of Oxfordshire and heavy rain caused flash-flooding and minor landslips in parts of east Devon. The Exmouth and Budleigh Salterton areas were worst affected. Southern Britain lay under a cold pool on 18th beneath which some areas of heavy rain drifted aimlessly around. Some of the rain was particularly

heavy, especially in parts of the north-east Midlands and East Anglia. At Halesworth (Suffolk) 60mm were recorded in 12 hours and at Skegness (Lincolnshire) 25mm fell. Southern counties reported thunder early in the day and the north Midlands were quite badly affected in the early hours and again in the evening. At Bawtry (South Yorkshire) lightning smashed a hole two metres across in the gable wall of a house and another house was damaged at Rotherham, both incidents occurring in early morning storms. Flooding was widespread. Although many areas remained dull on 19th the sun came through quite strongly across southern counties of England and here thunderstorms developed in parts of Kent and Sussex. Torrential downpours accompanied some of the storms, not least at Maidstone where 25mm fell in 45 minutes.

A showery trough moved eastwards across the country on 24th and thunder was reported in places, mainly from Dorset to Essex. In the early hours of 25th thunder was heard in the Isle of Man and in the afternoon and evening thunder accompanied outbreaks of heavy rain in south-western counties of England and Wales. In the late morning and afternoon of 26th some heavy thundery showers affected southern counties of England, particularly the south-west, and in the evening more widespread thunderstorms accompanied a deep trough as it pushed into south-east England giving some quite intense and prolonged activity that lasted well into the early hours of 27th. Rainfall was locally very heavy in southern parts of Sussex and Kent were 60mm fell at Worthing and 73mm at Kent. During the morning of 27th thunder was heard in parts of south-west Scotland and the Isle of Man and in the afternoon more thunderstorms moved into south-west England and south Wales, spreading to Dorset, Hampshire and West Sussex in the evening. This latter area of storms transferred eastwards to affect East Sussex and Kent in early hours of 28th and for the second night in succession many places near the Channel coasts were subjected to prolonged storms and torrential rain giving 25-50mm in a number of places. At Herstmonceux (East Sussex) a gust of 85 knots was recorded during the passage of what is believed to have been a short-lived tornado. At Southsea lightning struck and damaged a block of flats. No-one was injured but the top floor was extensively damaged as was a car parked nearby when masonry fell upon it. All the storms had died out well before dawn but in the late afternoon an isolated thunderstorm was reported in the Merseyside area. Showers developed widely over the U.K. and Ireland on 29th and many were accompanied by hail and thunder, particularly in the west. The 30th was also a very showery day in the circulation of a complex depression lying over Scotland, and thunderstorms developed widely over England and Wales, south of a line from Mersey to Humberside, many accompanied by hail. Again activity was most spectacular in the south-east with considerable lightning over the eastern English Channel. Some of the storms continued in the south-east into the early hours of 31st with an isolated report of thunder in the Belfast area of Northern Ireland.

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Climatological Observers Link and also to the London Weather Centre for information published in the Daily Weather Summary.

WORLD WEATHER REVIEW: September 1990

United States. *Temperature:* mostly warm; third warmest September since 1895; +4degC from N. Idaho to N.W. Utah and N. Wyoming. Cold from Ohio and E. Virginia to parts of Maine; marginally in W.S. Texas; -1degC from Maryland to N. New York. *Rainfall:* 10th driest September since 1895. Wet from Arizona to W. Wyoming, W. South Dakota, W. Texas and Arkansas; N. Wisconsin. to N. W. New York; E. North Dakota; N.E. California into Nevada; most of Hawaii. Over 200% in S. and extreme N. New Mexico, W. Texas, C. and S. Colorado, N. Wisconsin, N.E. Ohio, S. Hawaii; parts of Arizona. Dry elsewhere; under 50% from Pacific coast to Nevada and Montana; Nebraska to N. Illinois and N. Missouri, Alabama and much of Florida to parts of Pennsylvania; parts of coastal Texas.

Canada and Arctic. *Temperature:* warm from S.E. Alaska to Manitoba and S. Ontario; N.E. Greenland, Spitzbergen; +3degC in S. Alberta, W.S. Saskatchewan, Spitzbergen. Cold elsewhere; -2degC from N. Quebec to Keewatin district; locally in S.E. Greenland. *Rainfall:* wet from Alaska to S. Baffin Island and parts of S.W. Greenland; Great Lakes to W. Newfoundland; N.E. Greenland. Over 200% in W. Canadian Arctic islands; locally in W. and S. Alaska, Mackenzie basin and N.E. Greenland. Dry elsewhere; under 50% from Canadian Rockies to N. Ontario; Bjornoya; locally in S.E. Iceland. No data available for Franz Josef Land.

South and Central America. *Temperature:* warm in E. Brazil; most of Mexico to Honduras; marginally in C. Chile; +2degC locally from S. Mexico to Honduras. Cold in most of South America 15-40°S; interior N. Mexico; -2degC from Paraguay into S. Brazil. *Rainfall:* wet in E. Paraguay, S. and C. Brazil, C. Chile, C. Argentina, N. Mexico, N. Belize, C. Honduras. Over 200% from S.E. Paraguay into Brazil; N. Mexico. Dry in N. Chile, W. Bolivia, W. Paraguay, N. Argentina, N.W. coastal Mexico, S. Mexico to parts of Honduras; most of Uruguay. Under 50% at least locally in all these areas; widely in N. Chile, W. Bolivia, N. Argentina, S. Mexico to S. Honduras.

Europe. *Temperature:* warm in Portugal, Spain, W. France, N. Norway; part of W. and S. Italy; +2degC in most of Spain. Cold elsewhere; -2degC in parts of Germany and S., N. and extreme W. European Russia; C. and E. Poland, S. Hungary, N. W. Rumania. *Rainfall:* mostly wet; over 200% from S.E. Sweden, N. Germany and E. Czechoslovakia to C. Volga basin. Dry in Ireland, France, Italy, Balkans, N. Norway to N. coastal European Russia; most of Great Britain (except N. Scotland), Portugal, Spain and Belgium. Under 50% at least locally in all these areas (except perhaps Belgium), especially Ireland, N. and S. Spain, S. Yugoslavia, Greece; N. Norway to Arkhangelsk area; most of France and Italy; much of Romania. Provisional sunspot number 125.

Africa. *Temperature:* warm in Madeira, Canary Islands, Morocco, Algeria; most of South Africa; +2degC from N.E. Morocco to N.E. Algeria; N.W. Cape Province. Cold in E. Transvaal (-1degC) and Natal. *Rainfall:* wet from C. Morocco to N. Tunisia (over 200% locally); Madeira (over 200%). Dry in Cary Islands; W. and S. Morocco to S. Tunisia; South Africa; much of coastal Algeria and N. coastal Tunisia. Under 50% widespread in all these areas, including almost all of South Africa.

Asian U.S.S.R. *Temperature:* mostly cold; warm from Kazakhstan and Turkmenistan to E. of L. Baikal (locally +2degC, especially in S. Kazakhstan); New Siberian Islands probably to Taimyr Peninsula. Cold elsewhere; -2degC in C. Ob basin and n. of Sea of Okhotsk. *Rainfall:* wet in a band from most of Urals through C. Ob and C. Yenisey basins to Lena estuary and much of N.E.: over 200% near N.E. coast. Dry elsewhere; under 50% from much of Kazakhstan southwards; upper Lena basin, S. Kamchatka.

Asia (excluding U.S.S.R.). *Temperature:* warm in W. and N. Pakistan, S. India, Bangladesh, Korea, Japan, Thailand; most of China and Philippines; much of Middle East; +2degC in N.W. Pakistan; locally in C. China and C. and S. Japan. Cold in Cyprus, N. India; most of Turkey; locally in N.E. and S. China; -1degC in Cyprus, N.C. India; parts of Turkey. *Rainfall:* wet in W. Turkey, N.

and S.E. Pakistan, N. India, N. Bangladesh, E. and parts of S. China, Korea, Japan. Over 200% in C. Turkey, C. Korea; locally in N. Pakistan, E. and S. China and S. Japan; very locally in N. India. Dry from E. Turkey to S.W. Pakistan; S. India, S. Bangladesh, C. and W. China; most of Mongolia, Thailand and Philippines. Under 50% very locally in Bangladesh, Thailand and Philippines; widely in the other areas; largely rainless in Middle East.

Australia. *Temperature:* warm (+1degC) in S.W. half; cold (-1degC) in N.E. half. *Rainfall:* wet locally on S.W. and S.E. coasts and even more locally on N.E. coast, otherwise dry; under 50% general except in S.

M.W.R

WORLD WEATHER REVIEW: October 1990

United States. *Temperature:* warm from E. coast to Alabama and E. Ohio; California to S. Idaho, W. Wyoming and New Mexico; Hawaii; +2degC from coastal South Carolina to Cape Cod; locally in S. California and S. Arizona. Cold elsewhere; -2degC locally in E. Oregon. *Rainfall:* wet from E. coast to Texas (except N. and S.), Wisconsin and S. Missouri (except most of Gulf Coast); from N. Wisconsin S.W. to Colorado; in and near N. Idaho; coastal Oregon and Washington; extreme S. Hawaii. Over 200% widely from Maine to Georgia; C. Ohio and S. Michigan to Arkansas; in and near N. Idaho; extreme S. Hawaii. Dry elsewhere; under 50% in most of an arc from Dakotas through N. Montana, N. Nevada and California to New Mexico, S. Kansas and W. Oklahoma; parts of E. Mississippi, W. Alabama and coastal Texas; N.W. Hawaii.

Canada and Arctic. *Temperature:* warm only in extreme N.E. Alaska (+2degC), Bjornoya and marginally in S.E. Iceland. Cold elsewhere; -3degC in interior W. Canada, Franz Josef Land, in and near N. Baffin Island. *Rainfall:* wet in W. Alaska, W. coastal Canada and then along a band through Canada near 60°N., then through Labrador and Newfoundland to Great Lakes; Franz Josef Land, extreme N.E. Greenland, Spitzbergen, Bjornoya. Over 200% at least locally except perhaps in last two areas; more widely in Maritime Provinces. Dry elsewhere; under 50% from parts of S. Alaska to W. Canadian Arctic islands; S. Saskatchewan, S. Manitoba; much of Greenland.

South and Central America. *Temperature:* warm almost everywhere in South America 15-40°C; extreme N.W. Mexico; S. Mexico to Honduras; +2degC from C. Argentina to S.E. Brazil. Cold in most no N. (-1degC) and C. Mexico. *Rainfall:* wet in most of N. and C. Argentina, Uruguay, C. Paraguay, extreme S. Brazil and N. and C. Mexico. Over 200% widely in N. Mexico; locally in N. and C. Argentina. Dry from N. and C. Chile into W. Argentina; most of Bolivia; much of S. Brazil; parts of N.W. and S.E. Paraguay; extreme N.W. and N.E. Mexico; S. Mexico to Honduras. Under 50% at least locally in all these areas except perhaps S.E. Paraguay; widely from N. and C. Chile into W. Argentina and W. Bolivia; E. Bolivia.

Europe. *Temperature:* mostly warm; +2degC from most of France to W. and S. Germany, Belgium, Switzerland and C. Italy. Cold in N. European Russia; -3degC in N. Urals. *Rainfall:* wet in British Isles, Portugal and W. and N.E. Spain, France, S. Belgium, S. Germany, Switzerland, Austria, S.E. Czechoslovakia, N. and W. Italy, Corsica, Sardinia, S. Sweden; most of Hungary; much of European Russia (except extreme N. and S.). Over 200% at least locally except perhaps in Switzerland, Austria, Sardinia, Hungary and S. Sweden; widely in Portugal and near S. Urals. Dry elsewhere; under 50% from C. Norway to C. Finland; N.E. Germany, N.W. and S.E. Poland, W. Ukraine, lower Volga basin, Greece to much of Romania and interior Yugoslavia; S. Italy, extreme S.E. Spain. Provisional sunspot number 145.

Africa. *Temperature:* warm from Canary Islands to Egypt; in and near most of South Africa; +3degC from W. Algeria to W. Libya. Marginally cold near South African coast. *Rainfall:* wet on coast of Natal and S.E. Cape Province; parts of S. Botswana and Transvaal. Dry from Canary Islands to Egypt; in and near most of South Africa; under 50% general.

Asian U.S.S.R. *Temperature:* mostly warm; +5degC E. of L. Baikal and in upper Lena basin. cold near Arctic coast, S. to C. Ob basin; marginally near Iran border; -3degC round Gulf of Ob and in N. Urals. *Rainfall:* mostly wet; over 200% in W. Uzbekistan; widely in S. Urals and upper Ob

basin; parts of S. Kazakhstan; locally in Lower Tunguska and lower Lena basins and round Okhotsk. Dry from Mongolian border and parts of upper Lena basin to Kamchatka; round N. Caspian Sea; locally in Kazakhstan; under 50% in all three areas, especially first.

Asia (excluding U.S.S.R.). *Temperature:* warm in W. and E. Turkey, Mongolia, Korea, Japan, Thailand; most of China and Philippines; marginally in S. and locally in N. India; +3degC in W. and E. Mongolia, N.E. China. Cold in Pakistan, Bangladesh; most of India; parts of S. China; -1degC fairly widely in all these areas. *Rainfall:* wet in extreme N. Pakistan, S. Mongolia, S. Japan, W. Malaya, E. Philippines; most of W. Turkey and Thailand; much of India, Bangladesh and C. China; part of E. coastal Korea. Over 200% in C. India; parts of C. China and C. Thailand; locally in extreme N. Pakistan. Dry in E. and extreme W. Turkey, N. and parts of S. India, E. and S.W. China, N. Mongolia, N. Japan, N. Thailand, E. Malaya; widely in Pakistan, N.W. India, E. and S.W. China, N.W. Mongolia, Korea.

Australia. *Temperature:* mostly warm; +2degC in Northern Territory. Marginally cold in S.W. and parts of E. *Rainfall:* wet near much of S. coast (locally over 200% in S.W.) and in C. Northern Territory; otherwise mainly under 50%.

M.W.R.

WEATHER SUMMARY: February 1991

February 1991 will best be remembered for the severe cold spell that affected most places during the first two weeks. Southern counties were subjected to the worst of the icy blast while in northern areas of Britain the cold spell was nothing like as severe. Mean temperatures were around two and a half degrees Celsius below the average in the south-east of England, near one and half below in central areas and not far below in the far north of Scotland. Although it was a cold month overall, the last week saw temperatures well above the normal, reaching 14.7° at Yatton (Avon), 14.5° at Waddington (Lincolnshire) and 14.3° at Louth (Lincolnshire) on 23rd, 14.8° at Buxton (Norfolk) and 14.7° at Minehead and Weston-super-Mare (Somerset) on 26th. Parts of eastern Scotland had temperatures around 12° or 13° on 23rd and 26th. There were no warm nights of any consequence, reports of 12° minima in east Wales on 23rd being the highest recorded anywhere.

The arrival of intensely cold air from Russia was marked by four or five days with extremely low maxima. On 7th Bastreel (Cornwall) recorded -5.7°C and at Hastings the temperature rose to only -5.5°C, while -4.8° was recorded at Epsom Downs (Surrey) and Brighton (East Sussex). On 8th -6.5°C was the maximum recorded at Brede, near Hastings (East Sussex), with -4.0° at Folkestone and Herne Bay (Kent) and on 9th -5.5° was reported at Buxton (Derbyshire). Lowest minima included -12.0°C at St. Harmon (Powys) on 2nd, -11.7° at Yeovilton (Somerset) on 9th and -14.5° at Barbourne (Hereford and Worcester) and -14.0° at Madley, near Hereford on 10th. On 13th -14.1°C was recorded at Rannoch School, Dall (Tyneside) and on 14th -15.6° was recorded at Barbourne and 13.8° at Braemar (Grampian). Frost on the grass was also very severe with the following notable values; -16.8° at Gatwick on 7th, -17.4° at Gatwick on 9th, -18.2° at Velindre (Powys) on 10th, -16.5° at Pencelli (Powys) on 11th and -17.5° at Stansted (Essex) on 14th. February was a dry month in most central areas of England and Wales with little more than 50 per cent of the

normal in places. However, although northern areas of Scotland were dry most other parts of Scotland and the extreme north of England had a wet month, and rainfall was a little above the average in parts of eastern England and in west Cornwall. The wettest weather of the month accompanied the northward progress of very mild air on 22nd and 23rd. On 22nd Machynlleth (Powys) recorded 133.5mm and 57.5 mm fell at Cilfynydd (Mid Glamorgan) while on 23rd 37.4mm fell at Eskdalemuir (Dumfries and Galloway). Other daily totals of note included 25.9mm at Kilmallock (Co. Limerick) on 3rd, 22.7mm at Carlton-in-Cleveland (Cleveland) on 10th, 27.1mm at Nantmor (Gwynedd) on 14th, 21.1mm at St. Ives (Cornwall) on 15th and 26.5mm at Gwennap Head (Cornwall) on 16th. Later in the month Bedford recorded 29.4mm on 27th. Sunshine totals were generally above the normal in the west of the U.K. and below in most central and eastern parts.

The month opened with high pressure becoming established over Scandinavia and as it intensified to around 1054 mbar on 4th all parts had a spell of dry weather with cold easterly winds and widespread frosts by night and with good spells of sunshine by day. The easterly flow strengthened during 5th and until 10th temperatures remained below freezing both by day and night over most central and southern counties of Britain and snow showers spread from the east coast to affect many parts of Britain over the next few days. An occlusion moved across south-eastern counties of England on 7th, producing more widespread snowfalls in these parts and on 8th a low pressure area moved slowly into the English Channel. Many places from the south-east to northern England received considerable accumulations of snow during this period, between 10 and 20cm quite widely, and by 10th some places, mainly in the east were reporting 30cm or more of level snow. By 10th the bitterly cold easterly flow had been replaced by a less cold north-westerly but on 12th a small disturbance slipped south-eastwards across Britain into the English Channel and as it did so rain in the west turned to snow in many northern, central and eastern counties producing a further 10cm in places. By 13th it had become considerably less cold by day, although still frosty at night with some locally very low minima, and by 15th many western parts had their first frost-free night for some considerable time as frontal systems pushed in from the Atlantic.

On 16th and 17th further small depressions slipped south-eastwards across Britain and on 20th, as Atlantic fronts pushed into the country from the west, a small low moved north-east across northern Britain giving some heavy rain in places and snow over parts of Scotland. A major change to a very mild south-westerly airstream spread to all parts on 22nd, preceded by heavy rain, and a rapid thaw of lying snow resulted in serious flooding adjacent to upland areas, particularly in and around the city of York. A southerly flow maintained the mild weather throughout the rest of the month and as frontal systems crossed the country from time-to-time most parts had a little rain at times although clear skies on some nights resulted in a little frost and quite widespread fog.

K.O.M.

TEMPERATURE AND RAINFALL: FEBRUARY 1991

	Mean		Max	Min	Grass	Rain	%	Wettest	RD	TL
	Max	Min								
BELGIUM: Uccle	3.2	-3.3	16.6(24)	-13.1(7)	-14.5(7)	37.7	71	8.4(15)	15	
" Rochefort	3.7	-7.8	17.4(26)	-17.2(7)		26.2	50	4.0(15)	12	-
" Liège	3.9	-3.1	16.9(24)	-11.4(7)		26.4	53	8.0(15)	12	-
DENMARK: Fano	1.3	-2.4	7.5(26)	-11.6(13)		30.9	78	7.2(23)	11	0
" Frederikssund	1.5	-3.1	9.6(24)	-7.2(18)	-15.8(17)	33.1	129	8.3(12)	12	0
GERMANY: Berlin	0.8	-5.3	12.9(24)	-12.9(6)	-14.2(12)	27.1	78	7.9(10)	13	0
" Hamburg	1.3	-4.8	14.1(24)	-11.9(6)	-17.0(13)	26.1	65	5.6(24)	16	0
" Frankfurt	2.9	-4.9	13.8(24)	-12.6(6)	-13.6(9)	19.5	50	5.8(15)	13	0
" München	1.6	-7.8	14.8(25)	-16.8(6)	-18.9(7)	18.8	34	6.9(15)	11	0
MALTA: Luqa	15.4	9.3	18.3(6)	6.3(2)	-0.5(2)	74.8	122	19.3(20)	10	6
NETHERLANDS: Ten Post	1.9	-3.9	12.5(24)	-10.1(11)	-14.7(9)	24.0	55	10.5(16)	10	0
SWEDEN: Valla	-0.4	-5.4	9.1(24)	-19.0(16)		21.5		6.8(23)	15	0
SWITZ'D: Basel	5.0	-4.3	18.2(25)	-14.0(7)		18.3	46	6.5(9)	12	1
EIRE: Straide	7.2	-0.3	11.5(22)	-5.5(10)	-13.5(10)	85.9	105	17.3(3)	20	0
" Mt. Russell, Limerick	6.3	0.8	11.8(22)	-5.2(8)	-8.3(8)	106.8		25.9(3)	19	1
SHETLAND: Whalsay	5.2	1.8	8.5(23)	-2.5(12)	-9.2(10)	57.9	69	9.9(22)	16	0
" Fair Isle	5.1	2.6	8.0(23)	-1.6(11)	-5.8(8)	49.4		18.6(21)	19	0
SCOTLAND: Braemar	2.6	-3.1	8.2(24)	-13.8(14)	-15.0(14)	61.0	91	13.3(8)	14	0
" Inverduie	4.1	-3.0	11.9(26)	-10.2(1)	-14.8(13)	43.4	67	9.9(28)	14	0
" Rannoch	3.8	-4.8	8.5(23)	-14.1(13)	-14.1(13)	89.2		26.0(22)	8	0
WALES: Velindre	5.0	-2.5	12.0(26)	-11.6(10)	-18.2(10)	65.4	112	20.4(21)	13	0
" Carmarthen	5.1	-1.6	11.1(24)	-8.2(10)	-13.2(10)	84.4	99	24.1(22)	15	0
" Gower	5.4	-0.3	10.4(24)	-8.2(10)	-12.8(10)	70.2	87	15.6(22)	13	0
GURNEY: Airport	5.8	1.9	11.2(25)	-7.2(7)		48.0		11.4(12)	14	0
JERSEY: Carrefour/Clq	6.7	1.0	13.4(25)	-8.5(7)		45.8		10.3(15)	12	0
ENGLAND:										
Denbury, Devon	5.8	0.4	11.3(26)	-8.5(7)	-9.2(9)	67.7	69	37.3(22)	12	0
Gurney Slade, Som	4.5	-3.8	11.9(26)	-11.0(10)	-13.7(10)	53.7	43	13.0(14)	15	0
Yatton, Avon	6.1	-0.9	14.7(23)	-7.4(7)	-10.7(10)	39.0	70	12.8(22)	10	0
Reading Univ, Berks	4.9	-1.4	12.2(23)	-7.9(7)	-11.3(9)	29.9	73	10.2(27)	12	0
Sandhurst, Berks	5.2	-2.3	11.7(23)	-10.1(10)	-12.0(10)	43.1	89	11.7(27)	14	0
Romsey, Herts	5.4	-1.9	11.3(23)	-9.9(10)	-14.0(10)	39.9	75	13.9(22)	14	0
Brighton, Sussex	4.5	-1.1	10.2(24)	-9.6(7)	-9.6(7)	45.0	82	11.1(12)	11	0
Hastings, Sussex	4.2	-0.5	10.8(24)	-9.2(7)	-9.5(7)	46.0	90	6.4(21)	14	0
Dover, Kent	4.4	-0.6	12.0(24)	-7.9(7)		39.5	67	10.4(8)	14	0
East Malling, Kent	4.9	-1.4	13.5(24)	-9.5(7)	-12.5(14)	39.9	86	10.8(12)	-	0
Epsom Downs, Surrey	4.5	-1.8	11.5(24)	-12.9(10)	-15.5(10)	43.0	86	12.8(27)	17	0
Reigate, Surrey	4.4	-1.5	11.3(24)	-10.9(7)		47.4	100	10.7(27)	17	0
Guildford, Surrey	4.7	-0.9	11.0(24)	-10.2(7)	-12.5(7)	40.8	86	13.0(27)	14	0
Sidcup, London	5.2	-1.4	13.2(24)	-8.0(7)	-12.2(10)	46.9	137	11.9(7)	12	0
Hayes, London	4.8	-1.4	11.9(23)	-8.5(10)	-9.5(10)	41.0	112	15.3(27)	14	1
Hampstead, London										
Royston, Herts	4.4	-0.8	13.1(25)	-9.4(9)	-12.0(9)	43.3	123	13.4(7)	13	0
Loughton, Essex	4.3	-1.2	12.9(24)	-8.2(10)	-17.1(9)	42.1	110	8.3(27)	12	1
Buxton, Norfolk	4.7	-1.0	14.8(24)	-9.8(10)	-12.5(11)	31.0	82	6.3(14)	13	0
Ely, Cambs	4.5	-2.8	13.8(25)	-10.2(14)	-12.0(10)	28.6	84	7.3(7)	12	0
Luton, Beds	4.3	-1.4	13.2(25)	-9.2(10)	-17.2(10)	56.7	130	25.2(27)	14	0
Buckingham, Bucks	4.2	1.7	12.8(25)	-9.3(10)	-17.3(10)	31.7	69	7.4(27)	13	0
Oxford University	4.7	-1.6	12.5(23)	-7.9(7)	-10.1(10)	20.5	50	4.4(27)	11	-
Birmingham University	4.5	-0.6	13.4(23)	-8.4(14)	-17.0(14)	46.3		21.7(7)	12	0
Wolverhampton, W.Mid	4.6	-1.3	12.2(23)	-7.6(7)	-13.0(10)	39.1		11.1(7)	12	0
Louth, Lincs	4.9	-0.6	14.3(23)	-5.5(10)		53.0		18.8(27)	15	0
Keyworth, Notts	4.7	-1.1	14.4(23)	-9.8(9)	-17.0(10)	43.1	103	10.2(27)	14	0
Lowdham, Notts	5.0	-1.2	14.6(23)	-8.6(9)	-12.2(9)	45.9		14.7(27)	13	0
Derby, Derbys	4.9	0.0	13.6(23)	-7.0(10)	-9.3(10)	34.8	73	8.0(7)	16	0
Middleton, Derbys	2.6	-1.5	10.7(23)	-7.9(7)		68.2	87	12.7(7)	14	0
Keele Univ, Staffs	4.3	-1.6	11.8(23)	-7.5(10)	-9.9(12)	28.4	59	6.1(27)	10	0
Liverpool, Mersey	6.3	-0.1	13.4(23)	-4.4(7)		41.0	81	15.4(21)	14	0
Lathom, Mersey	5.3	-0.6	12.5(23)	-5.5(7)		53.6		23.7(21)	13	0
High Bradfield, S.York	2.1	-2.3	10.1(23)	-8.2(7)						
Carlton-in-Cleveland	4.4	-0.7	11.7(23)	-6.1(14)	-11.7(14)	101.9		22.7(10)	16	2
Durham Univ, Durham	4.9	-0.8	12.5(24)	-8.5(14)	-11.1(1)	80.0	209	13.0(27)	22	-
Sunderland, Tyne & Wear	5.6	1.3	12.6(24)	-2.3(14)		67.0	262	15.0(27)	17	2
U.S.: Bergenfield, N.J.	9.3	-2.2	22.2(5)	-11.1(16)	-13.9(16)	48.0		11.9(7)	9	0

	Mean		Max	Min	Grass	Rain	%	Wettest	RD	TL
	Max	Min								
JAMAICA: Kingston	31.2	22.0	34.5(1)	19.3(8)		3.8	23	3.7(14)	1	0
" Montego Bay	28.9	21.3	30.3(23)	17.6(11)		26.7	19	13.5(15)	8	0
AUSTRALIA: Leopold, Vic	24.5	13.0	39.2(25)	9.4(17)		3.7		3.7(16)	1	0

CUMBRIA RAINFALL: Carlisle 77.6mm (172%); Appleby Bongate 95.3mm (173%); Seathwaite 362mm (169%); Honister 380.0mm; The Nook Thirlmere 223.3mm (136%); Coniston 155.3mm (96%); Windermere, Whasdyke 139.8mm (129%); Grange-Over-Sands 69.8mm (96%).

CORRECTION to Jonathon Webb's paper on *Damaging Hail in 1989*. Page 79, March 1991 issue. Replace the last sentence of the second paragraph with the following:
Severe thunderstorms extended in a swath northwards through Oxfordshire during mid afternoon. Intense darkness preceded a storm at Brightwell cum Sotwell followed by hailstones the size of cherry stones, which fell for a few minutes. The storm which affected Oxford between 1430 and 1630 was exceptionally severe in the south-east of the City where many homes and shops were flooded. 68.5mm of rain fell at Sandford on Thames Sewage Works on the southern outskirts of the City. Squally winds and hailstones the size of large peas accompanied the storm, stripping leaves, blossom and small branches off trees. Hail of 10 to 20mm diameter was observed in the Headington district of the City (Jarvis 1990). Severe storms spread westwards later in the afternoon to affect Wiltshire, North Dorset, Somerset and East Devon.

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The charts of the Daily Weather Summary issued by the London Weather Centre comprise the following:

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FRONT COVER:

Surface synoptic charts for 5 January 1991 which brought storm-force winds to Northern Ireland

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