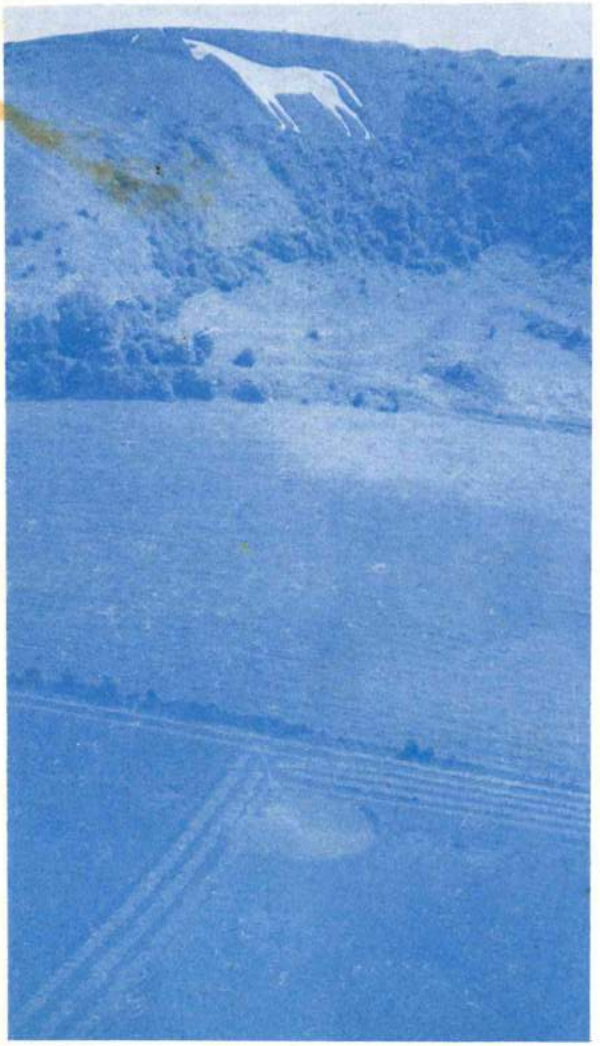
The JOURNAL of METEOROLOGY



A SUMMER DAY IN WILTSHIRE SHOWING THE WESTBURY WHITE HORSE AND, IN THE FOREGROUND, WHIRLWIND CIRCLES IN A FIELD OF OATS

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SNOW DEPTH AND SNOWFALL DISRUPTION IN SCOTLAND IN JANUARY 1984

By A. H. PERRY, L. SYMONS and P. WILLIAMS

Although snow depth is not the only factor determining the degree of disruption caused by heavy snowfall, it is probably a principal contender. Whereas the winter of 1983-84 was frequently mild, it will long be remembered for its storminess and in particular the snowstorms that affected Scotland and northern England during the third and fourth weeks of January. These were comparable in their impact to the blizzards of January 1978 (Perry and Symons, 1978). The recent publication of data on the frequencies of snow depth in Scotland for periods ending with the winter of 1981-82 (Meteorological Office, 1983) affords an opportunity to compare the depth of snow which accumulated in 1984 with that lying in other recent winters. The *Daily Weather Summary* produced by the London Weather Centre includes details of snow depths at a number of Scottish stations. The data for Eskdalemuir (Dumfries and Galloway) is particularly interesting. Since the winter of 1946-47, the maximum snow depth recorded at this upland station (height 242 metres) was 44 cm in mid-January 1963. In January 1984, level snow depth reached 39 cm by 1800 hours on the 18th and steadily increased over subsequent days, reaching 45 cm on the 22nd, 57 cm on the 23rd, 66 cm on the 24th and a maximum depth of 68 cm on the 26th. On the 23rd alone, the equivalent of 30 mm of rainfall was recorded at this station as a deep depression moved eastward from Northern Ireland across northern England to the North Sea. The quantity of snow which accumulated in the Southern Uplands was clearly unprecedented during at least 25 years and it is interesting to compare the depths noted with the extreme values for the other 100 Scottish stations given in the Meteorological Office publication. Extreme depths have reached 91 cm at Balmoral, but at only a few other stations have more than 60 cm been noted, notably Glenmore Lodge, Glenlivet and West Linton. In January 1978, 90 cm was noted at Clashnoir in the Grampians, although this station is not quoted in the recent Meteorological Office report. At Braemar, snow lay 58 cm deep this January, compared with the record depth there of 61 cm.

DISRUPTION

Until the middle of January, there was very little disruption from the weather, although high winds caused damage in the Hebrides and on the west coast of Scotland, and ferry sailings were affected. The second half of the month was, however, one of the most difficult periods ever for road and transport services, comparable in its effects in Scotland to the blizzards of January 1978. Whereas in that year disruption was severe in the Highlands but much less so elsewhere, in

1984 virtually the whole of Scotland suffered major interference to movement on the roads, and several trains were trapped in the snow, as had occurred in 1978.

Roads in the West, Central and Northern Highlands were blocked by snow for several days from 13 January. Drifts three metres deep on the A.82 were reported from Glencoe and Bridge of Orchy and large numbers of cars were abandoned, making access for snowploughs extremely difficult. Strathclyde police called in their mountain rescue team to take fifteen people from vehicles on the Rest and Be Thankful road to Arrochar. In the Borders, deep snowdrifts blocked the main A.74 south of Crawford. In the Lothians, traffic conditions were reported as chaotic and the A.69 was closed. Northward from Edinburgh, the M.90 and A.9 were blocked. By the evening of the 16th, closure affected 40 main routes in Scotland. In the extreme north, Wick was completely cut off. Southward, snow caused main road closures in Cumbria, the Peak District and on Teeside.

Before there could be complete recovery from these disruptions, the further blizzards of 20 January made matters much worse. Many diesel-engined vehicles were brought to a halt as fuel lines became blocked with fuel which had reached the waxing stage, temperatures well below that of –15 deg. C, for which winter diesel fuel in Britain is prepared, being widely experienced. Abandonment of vehicles again caused serious problems, 71 being abandoned on a 25 km stretch of the M.8 motorway into Glasgow. The Automobile Association reported more than 1,000 breakdown calls in the one day.

The snow gates on each side of Drumochter Pass were closed early in the afternoon of Saturday 21 January, but by this time some 200 cars, 30 lorries and five buses had become stuck in the drifts, and snowploughs, rescue and emergency vehicles also became immobilised. Over 350 people were taken to the security of Drumochter Lodge. Some 2,000 skiers were forced to spend the night at Glenshee ski centre, most of them in their own cars or hired buses. A convoy of about 500 cars and 27 buses moved south to Blairgowrie on the Sunday. At the Lecht ski centre, about 100 people were trapped for several days. the Rest and Be Thankful road in Argyll was again the scene of rescue work, 24 cars and four vans becoming stuck in the snow. In the Southern Uplands, hundreds of lorries were stranded on the A.74, and, in similar fashion, the A.68 was closed at Soutra and finally the blocking of the A.1 south of Berwick severed all road links with England.

Railways also suffered several local interruptions. Trains became snowed-in on the Drumochter Pass, on the West Highland line near Bridge of Orchy and in Caithness on the Inverness-Wick line. The main west-coast line from Glasgow to the south was more briefly blocked at Carstairs. Problems with overhead wires and frozen points also caused disruption to Glasgow suburban services. As on previous occasions, the railway problems were localised and solved with no direct casualties, although one evacuee who had a heart condition died after being airlifted from one of the trains. Numerous fatalities and serious injuries occurred on the roads, and other casualties included an ambulance man who suffered a heart attack in the course of rescue work and a power worker killed when the pole he was climbing snapped and fell. Exposure claimed the lives of some who set out to walk from immobilised vehicles, as well as climbers on the mountains.

As in 1978 in Scotland and in 1982 in Wales, the victims of the snow were far fewer than would have been the case without the work of helicopters. Search and

rescue helicopters of the Royal Air Force and Royal Navy were operated with minimal interruptions under appalling conditions, and were supplemented by civil helicopters. They rescued people from snowed-up cars, trains, shepherds' huts, and ships, and from homes in the cases of sickness and pregnancy, and delivered supplies to villages and isolated houses and fodder to livestock farms.

Airports, less vunerable to snow and ice because of the limited areas needing clearance and treatment, suffered closures to be counted only in hours rather than days, but these did briefly affect Glasgow, Edinburgh and Belfast airports.

On the night of 24 January, about 30 main roads were still blocked but the 100 skiers at the Lecht had been freed by snowploughs and, like other stranded travellers, had been able at least to start their journey home. The crisis was almost over but there was much clearing up to be done; thousands of households were still without power, telephones had still to be restored, and ways of meeting the costs considered.

By the time the thaw came towards the end of January, several regional councils had indicated that they had spent the entire budget allocated to winter maintenance. Such was the case with Tayside, which had budgeted £3,000,000, while Central Region's £816,000 budget had been exceeded by almost 50 per cent. Strathclyde had spent about £1,500,000, having distributed 60,000 tons of salt over their 12,000 km of roads with the help of 850 vehicles, including 320 specialised gritters. Other estimates of expenditure were, for Highland Region, between £2-£3,000,000; for Fife Region, £400,000 per week from a budget of £1,600,000; for Lothian Region, between £1,500,000 and £2,000,000 in two weeks; and for Dumfries and Galloway, £350,000 in a similar period. These represent only the costs of keeping the roads open, the capital costs being indicated by the cost of one new snow blower at £120,000. No estimate is known of additional costs incurred by the railways, bus companies and other services; to this must be added lost revenue and widespread insurance claims, which will be reflected in higher premiums, and costs to all concerned of accidents and lost days of work, restoration of electricity and telephone services, and other incidental costs.

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ANOTHER UNUSUAL BALL LIGHTNING INCIDENT

By MICHAEL W. ROWE

In the April 1983 issue of this journal (*J. Meteorology*, vol.8, p.125), I gave an account of an observation of rayed ball lightning at Blackpool, which I had received as a result of my appeal in the provincial press for reports of whirlwinds. This account, among other things, led me to widen the scope of my press appeal to include ball lightning. Among the several dozen reports of the phenomenon that I have received since, by far the best is the following. It was sent by Mr. James Huntingdon, of Fleetwood, Lancashire, after seeing my letter in the *Fleetwood Chronicle* of 27 January 1984.

"On the evening in question there was an intermittent thunderstorm with rain in heavy showers. My son Michael had just come in from the college and had gone into the room and was standing watching the T.V. The time would be a little before 6.00 p.m. I said something to the effect that his meal would be ready and he'd better wash his hands, etc., so he turned the television off, although it remained plugged in . . . At this point a spherical object about six inches (15 cm) in diameter floated down the (sealed) chimney and into the room. It appeared to be rather like a soap bubble but was a dull purple in colour covered or rather made up of a furry/spiky emission all over. The coating seemed to be about one inch (2.5 cm) thick with spikes of two inches here and there but changing all the time. It was quite dim and appeared to be semi-transparent, in so much as I could see through to the *inside* of the opposite side, which appeared quite smooth – all the spikes pointing outwards from the surface. It appeared to me to be insubstantial and made no sound.

It drifted between the two of us towards the television screen at about 30 inches (75 cm) from the floor, covering the six feet (2 m) in about four seconds. When about eight inches from the screen it disappeared (imploded?) with a fairly loud crack/pop sound leaving behind a smell as of an electrical discharge."

Mr. Huntington is to be commended on the excellence of this report, which has several classic features. The tendency for ball lightning to appear indoors, especially near or from chimneys, has been noted frequently. The low luminosity is also not uncommon. The 'spikes' are more unusual, but may be the same as the 'chains' in the Blackpool case mentioned above.

In an attempt to discover the date of the event (which Mr. Huntington said was "five years ago last November") *Daily Weather Report* data for Squires Gate (Blackpool Airport), about 15 km to the south of Fleetwood, were examined for November 1978. No observations of thunder or lightning were found duuring the period 1500-2100 GMT. A wider search, covering the months October to December in the years 1977-1979, revealed only three cases of thunder or lightning at Squires Gate between 1500 and 2100 GMT, all in 1979. The first, on 14 October, can be ruled out because it was a Sunday, whereas Mr. Huntington's letter makes it clear that the incident occurred on a weekday. On the following day, 15 October, there was a thunderstorm but it did not begin until after 1800, and no cumulonimbus was reported in the 1800 observations. This leaves 3 December 1979 which fits perfectly: it was a Monday and the thunderstorm was between 1700 and 1800 GMT.

It is interesting that 3 December 1979 was also the date of a tornado at Garstang, about 16 km east of Fleetwood. By coincidence, before I realised the probable date of the ball lightning incident, I had put a letter in the *Garstang Courier.* This produced a reply from Mr. B. Jenkinson, who had experienced a tornado on 3 December 1979 at Carter's Farm (SD 387458) near Stalmine. This is on a west-east line from Fleetwood to Garstang and about 6 km east of Fleetwood. Mr. Jenkinson wrote: "The wind got up and the house shook – we thought the end had come – followed by thunder and lightning. A hut made of corrugated iron 20 feet by 12 feet was lifted clean out of the field about 150 yards to the west of us and . . . smashed to pieces in our orchard."

Assuming that 3 December 1979 was the date of the ball lightning event, it clearly formed in the same cell that later gave rise to the Stalmine and Garstang tornadoes. An association between ball lightning and tornadoes has been noted several times. The most recent British example was at Teignmouth, Devon, on 26 January 1984, when witnesses saw "a red ball rolling down the River Teign just before the tornado struck" (*Exeter Express and Echo,* 2 February 1984). Even more recently, on 8 February 1984, Mr. Harry Head of Faversham, Kent, saw "what looked like a red football" during the passage of a very active thundery cold front which had produced over a dozen tornadoes as it crossed Wales and England.

WHIRLWIND SPIRALS IN CEREAL-FIELDS: THE QUINTUPLET FORMATIONS OF 1983

By G. T. MEADEN

In previous issues of this journal we have reported on the puzzling spiral shapes which appeared in certain Wiltshire and Hampshire cereal-fields during the growing seasons of 1980, 1981 and 1982 (*J. Meteorology,* 6, 76-80; 7, 45-49; 8, 11-19, 216-217). The general outline of the flattened areas was usually circular (sometimes elliptical or oval) with the grain-stalks laid down clockwise and spiralling outwards from a central or near-central point. Other case-histories were discussed too, and the general conclusion was that whirlwinds were thought likely to be the common damaging agent. In most cases there was just a single isolated circle (or quasi-circle), but the 1981 Hampshire event consisted of a triple formation with one large circle flanked by a pair of smaller ones.

In 1983, as British meteorologists are well aware, Britain had one of its better summers of the century, with July proving to be the hottest in the 300-year record. At the same time, 1983 proved to be a bumper summer for the production of 'mystery' spirals (and for heat whirlwinds generally). Moreover, and entirely unexpectedly, some of the spiral formations turned out to be symmetrically complex systems in an extraordinary manner: as many as four sets in different parts of southern England were found to consist of a single circle attended by four smaller satellite ones.

The beauty of these sets of circles caught the attention of the national newspapers, and thence the imagination of the general public. The story about the manner and the sequence of several of the 1983 discoveries has been given by Ian Mrzyglod (*Probe Report,* vol.4 (issue 14), 4-11). Here, we shall simply summarise the main facts, many of which have not been detailed before.

SET 1. Set of five circles at Bratton, Wiltshire (NGR ST 902522, below and north-east of the Westbury White Horse), consisting of one large circle (15 m diameter) and four satellites (each 4 m diameter). The distance between opposite pairs of circles was about 40 m (centre to centre). Figures 1 and 2 include photographs taken soon after the discovery of the circles. Relative to the main centre, the satellites are N.N.W., N.E., S.S.E. and W.S.W. of the centre. The B.3093 Westbury to Devizes road can be seen nearby. Figure 2 is a close-up view of the N.E. satellite. These circles were formed in early July (on the 3rd according to Paul

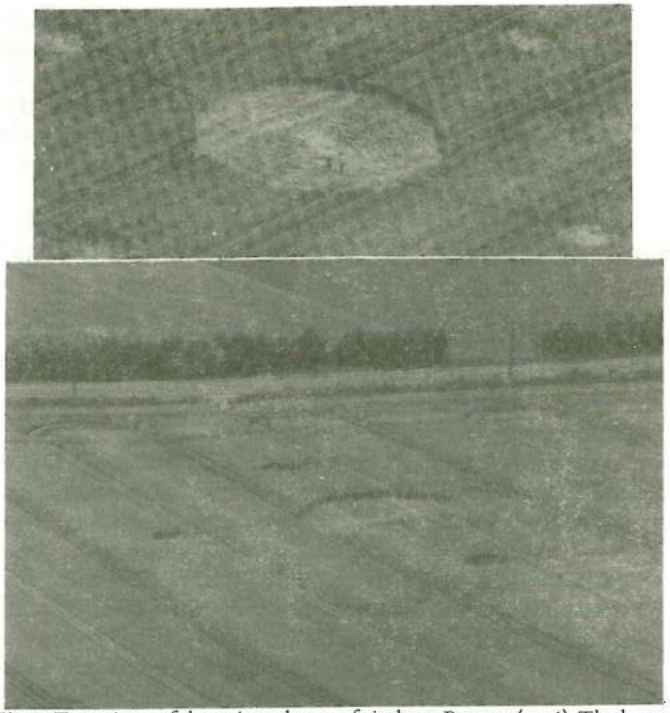

Fig.1: Two views of the quintuplet set of circles at Bratton (set 1). The lower photograph is by Ian Mrzyglod.

Millard of the *Wiltshire Times*). They were inspected by Ian Mrzyglod on the 8th and the author on the 9th. The 3rd was a continuously sunny day, maximum 25.4 °C (wind light N.W. at 0900 GMT).

SET 2. A single flattened area in a distant corner of the same field as set 1 but about 300 m away (ST 904520). It appeared to consist of two slightly overlapping circles, each of diameter 10 m with centre displaced by about 2 m. Seen by Ian Mrzyglod and the author late afternoon on 9 July; Ian was certain that it was not there 22 hours previously. The 8th and 9th were hot days, maximum 29 °C, with little wind and with fog around dawn on both mornings. The 8th had 8 hours sunshine and variable cloud; the 9th had 6 hours sunshine in the morning, but the afternoon and evening were cloudy.

SET 3. Two swathes of damage, each about 15 m wide and 80 m long, parallel to one another and nearly parallel to a N.W.-S.E. steep lane at ST 882509 above Westbury town. Clockwise spiral rotation within the damage swathes evident. Considered to have been formed by mobile travelling whirlwinds, probably late June or early July. Found by the author on 9 July and thought to be at least a week old then.

SET 4. Set of five circles at ST 844450 below Cley Hill which is near Warminster and not far from Longleat (Wiltshire). The large circle was about 15 m diameter.

Two opposite satellites were 3 m across, and the other two 4 m across; they were symmetrically disposed about the main circle like the Bratton set, but were much nearer to it, only 2½ to 4 m away in fact (the centres of the 3 m circles were 23 m apart, and the 4 m circles were 27 m apart). Found by the author on 9 July when they were evidently already several weeks old. According to the *Western Daily Press* of 23 July the farmer, Brian Hocken of Bugley Barton, found the set of circles in May but kept quiet about them because he said he did not want people trampling down his corn like they did the previous year. Note: Due to their distance from Cley Hill and the rather low angle of view, this set of quintuple circles was not easy to discern except by experienced observers from quite high up the hill; nothing could be seen from the A.362 road.

SET 5. One elongated 'circle' at ST 900519 below Bratton Castle and the Westbury White Horse. Apparently caused by a 4 m whirlwind making a neat circle and then travelling westwards a distance of 15 m while weakening rapidly. Photographed by Ian Mrzyglod on 13 August when it was already some days (or weeks) old.

SET 6. One circle, diameter 18-19 m, at ST 871474, about 50 m east of the A.350 Westbury to Warminster road near Upton Scudamore. The circle could just be seen from the main road; the escarpment of the Warminster Downs was about 500 m beyond. This circle was 4 km N.E. of the Cley Hill quintuple set and 3½ km S.S.W. of the whirlwind tracks of set 3. The circle was discovered and photographed by Ian Mrzyglod on 6 August; a photograph was also printed in the *Wiltshire Times* on 19 August.

SET 7. Set of five circles in a barley field below Cheesefoot Head near the A.272 Winchester to Petersfield road in Hampshire (SU 530281). The 80-acre field is owned by Lt. Comm. Henry Bruce. The principal circle was 18-19 m across and the satellites were about 5 m in diameter (Fig.3). The distance between the centres of opposite satellite pairs was about 60 m. They were featured in the *Western Daily*

Fig.2: A close-up view of the N.E. satellite, diameter 4 m, photographed on 9 July 1983.

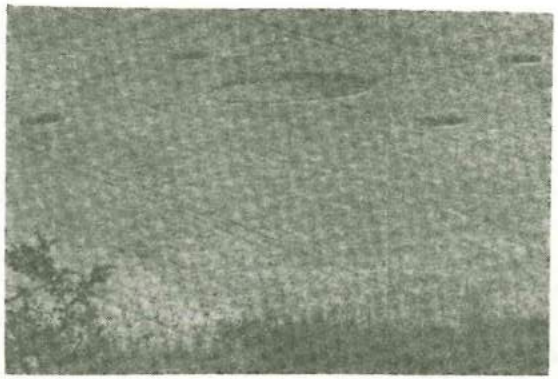

Fig.3: The quintuplet set of circles at Cheesefoot Head (set 7).

Press and the *Daily Express* on 12 July, according to which Mr. Maurice Botting (manager of a farm at nearby Owslebury) said they were not there on 18 June but were there at 0630 on 19 June: "In each circle the barley has been knocked down scientifically in a clockwise splayed spiral from the centre leaving a perfect arc. The barley is laid perfectly, not ripped, torn, or crushed." According to Pat Delgado in *Flying Saucer Review,* vol.29, no.1, 14-16, he was told that the rings were not there on Sunday evening, 19 June, but were there the next morning. (Both days, 18th and 19th, were warm and sunny with north-east winds, but the sky became overcast during the night of 19th/20th).

The Cheesefoot Head punch-bowl was also the site of a triplet formation in 1981, the 1983 quintuplets occurring in almost the same place. Mr. Delgado also mentions that there were other circles in 1981, at Three Maids Hill near Worthy Down, north-west of Winchester, and at a third site in the district which lay on a straight line on a map compared with the other two. The farmer also said that circles were found in 1980 as well.

SET 8. Set of five circles in a field of wheat just below the Ridgeway near Wantage in Oxfordshire. Diameter of main circle about 16 m, diameter of each satellite about 4 m, distance between centres of opposite satellite pairs 44-45 m (Fig.4). The field is owned by Mr. David Castle of Charlton Village, 3 km away; the first circles were 12 m into the field from the main road (SU 4488). According to the *Swindon Advertiser* of 19 July and the *Gazette and Herald* of 21 July, the rings appeared 'at the weekend', namely round about Saturday 16 July. The 15th and 16th were hot, almost cloudless days, with maxima of about 32 °C (90 °F).

PRELIMINARY DISCUSSION

The appearance of these beautiful quasi-uniform sets of circles with their neat spiral patterns and sharp perimeter edges has evidently proved to be wholly perplexing, yet simultaneously entertaining to the general public. Even academics and scientists, unacquainted with the effects that natural vortex motions can produce, have been puzzled too. But we now regard these magnificent displays in their various forms (singlets, triplets, quintuplets) as voiceless witnesses to the unseen passage of whirlwinds in a multi-vortex state. The patterns in the fields are

like spoors, providing an intelligible trail for those with the experience to interpret them, and demonstrating that whirlwinds are capable of performing unusual feats which have yet to be seen in action (at least by scientific witnesses).

With singlet whirlwinds, and single spiral-patterned circles, there is basically no problem. Whirlwinds are relatively common occurrences, under the right weather conditions, in Britain in the summer months. TORRO has hundreds of cases in its records for all the months from April to September inclusive. A number of people have described whirlwinds flattening the grass in fields or lifting hay or haycocks into the air. One of these references is worth citing because it comes from Warminster, the observer being Mr. Arthur Shuttlewood (*NOW! U.K.,* 29 August 1980).

"One evening there were about 50 of us sky-watching along the Salisbury Road. Suddenly, the grass began to sway before our eyes and laid itself flat in a clockwise spiral, just like the opening of a lady's fan. A perfect circle was completed in less than half a minute, all the time accompanied by a high-pitched humming sound. It was still there the next day."

Regarding cases of multiple whirlwinds, observers from across the world have reported seeing whirlwinds with multiple vortices, sometimes long-lived, in association with hot weather (e.g. S. B. Idso, *Sci. American,* vol.62, 530-541). In some of the examples which I have found several small vortices appear to be circulating around a main vortex, following its perimeter. A thorough study of specific cases seems to have been rarely undertaken, but the observations of J. Hallett and T. Hoffer, coupled with ciné-film stills, are an excellent exception (*Weather,* vol.26, 247-250, 1971). The whirlwinds that they studied formed on a valley floor near Reno, U.S.A. in an apparent lee-eddy situation with regard to an adjacent 250 m high hill or escarpment on three successive days 2-4 September 1970.

"The most striking observation was that on many occasions a widespread circulation with a diameter about 100 m developed on the lower slopes. The central area (of the whirlwind) was quite clear, as can be seen in the series of photographs from the 16-mm film, printed at1.2-second intervals. Small dust devils formed at the periphery of this circulation and could be easily distinguished. They moved with a speed sometimes greater and sometimes less than that of the

Fig.4: The quintuplet set of circles below the Ridgeway near Wantage (set 8).

general rotation. These smaller dust devils formed at intervals of a few seconds for irregular periods of 2 to 3 minutes. Their linear velocity decreased as their local rotation rate increased. In contrast to this somewhat irregular circulation at lower levels, the circulation above about 10 m, which most smaller dust devils failed to reach, was quite steady.

The rotation of two such circulating systems, averaged over about 100 seconds, was 9 degrees/sec. and 6 degrees/sec, giving a (tangential) linear velocity of 7 and 4 m/sec. A few small dust devils originated at a considerable distance, 100 to 200 m, from the periphery of the larger circulation. These joined the main circulation by moving in along a tangent. Some were fully developed, extending upwards some 20 m, while others, originating closer in, were confined to a shallow layer some 5 m deep, and they appeared to be associated with a wave-like motion on a shallow layer of air moving into the main circulation.

These large circulations moved irregularly, in a direction parallel to the hill, that is, at right angles to the upper wind. The dust in the upper periphery of the circulation was moving upwards with a velocity of about 10 m/sec. Since the flow aloft was strong westerly, it appears likely that these circulations were associated with some form of lee eddy, as has been observed on an even larger scale for a well-developed lee-wave situation (J. Hallett, *Weather,* vol.24, 133, 1969). This observation stresses how important meso-scale circulation may be in providing regions of horizontal shear for generation of the initial rotation for dust-devil formation."

EXPLANATION

We are thus led to summarise the present state of knowledge as follows.

The singlet circles in cereal-fields are formed by singlet whirlwinds; the multiplet circles are formed by a master whirlwind attended by lesser satellite whirlwinds. Side and plan-views of the windflow within a circle-forming whirlwind are illustrated in Figure 5(a). The rising air-currents are strongest in the peripheral region and drop off rapidly outside. The centremost part of such a whirlwind is characterised by a feeble downdraught. The clockwise pattern at ground level in a cereal-field reveals the windflow of time past. The whirlwind would have begun with a narrow core, widening with time and flattening the crops over an increasing radius up to a certain limit after which stabilisation and then decay would occur.

Such whirlwinds would develop from pre-existing thermals which were set into rotation by some means. If the cause of rotation was entirely random in character, then anticlockwise whirlwinds would occur as frequently as clockwise ones. But, because all the circle cases so far discovered in Britain have displayed a clockwise pattern, one surmises that some external factor which leads to the rotation is common to them all.

In all the examples known to the author, escarpments or broad steep hillsides have been in the vicinity. The hills in question face N.N.W. and west at Bratton, west at Upton Scudamore, east at Cley Hill, north-west at Cheesefoot Head, and approximately north at Charlton, Wantage. Not surprisingly, the field boundaries are nearly parallel to the hill-faces, and the furrows and crop-distributions are parallel to both. The known multiplet circle-systems have their axes either

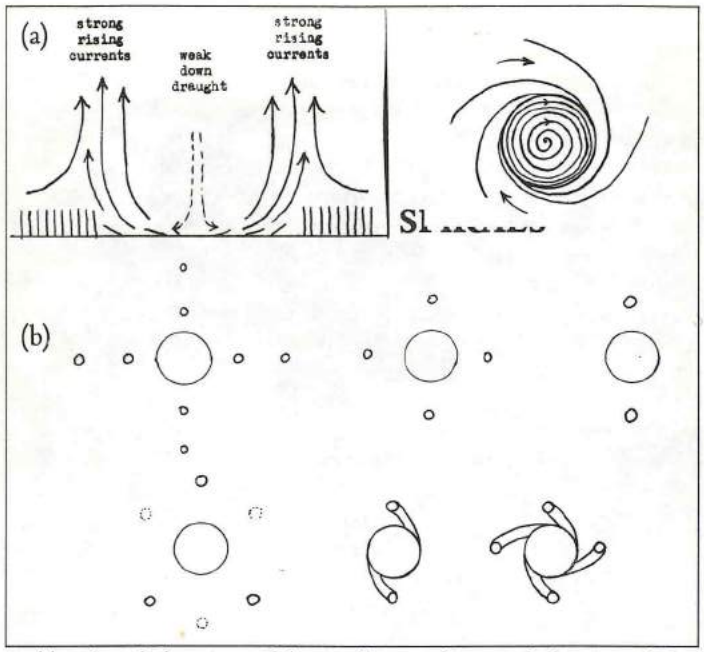

Fig.5: (a) Side and plan-views of the windflow within a circle-forming whirlwind.
(b) Some possible whirlwind patterns, known and unkown.

perpendicular or parallel to the field boundaries and to the hillsides; this could be understood if the whirlwinds form to the lee of the hills, and might also be understandable if they form to windward. Certainly, it remains to be proved, by succeeding in catching a whirlwind at work in a crop-flattening exercise, in what way eddies in the general wind-field can best set a thermal spinning. At any rate, it is already known that whirlwinds are not carried along with the general wind if the local wind-speed is no greater than 5 km/hr (see Idso, for example).

Next, we have reason to suspect that some of the circle-producing whirlwinds occurred late in the evening, possibly even at twilight or later, or (most unlikely) just after dawn. The afternoon and evening are most probable of course. Thermals develop readily over cereal-fields because the soil heats up well in the hot summer sunshine when the sun is high in the sky (the ratio of exposed bare earth to the area occupied by a thin plant-stalk is considerable indeed, the rows being about 15 cm apart and the plants within a row a few cm apart). Because the earth retains its heat very well, the thermals would persist into late evening in high summer, possibly even after dark. It is also possible that when the thermals are in a weaker state, as in the late evening, they are more vulnerable to odd alterations in the general windfield with a greater susceptibility to acquire a rotational state.

Be that as it may, we can at any rate suppose, from the nature of the observed 2-fold and 4-fold symmetry that all the circles of the quintuplet formations are linked to one another (through the air of the atmosphere) by a sort of standing-wave system with nodes and anti-nodes. In other words, the satellite vortices are

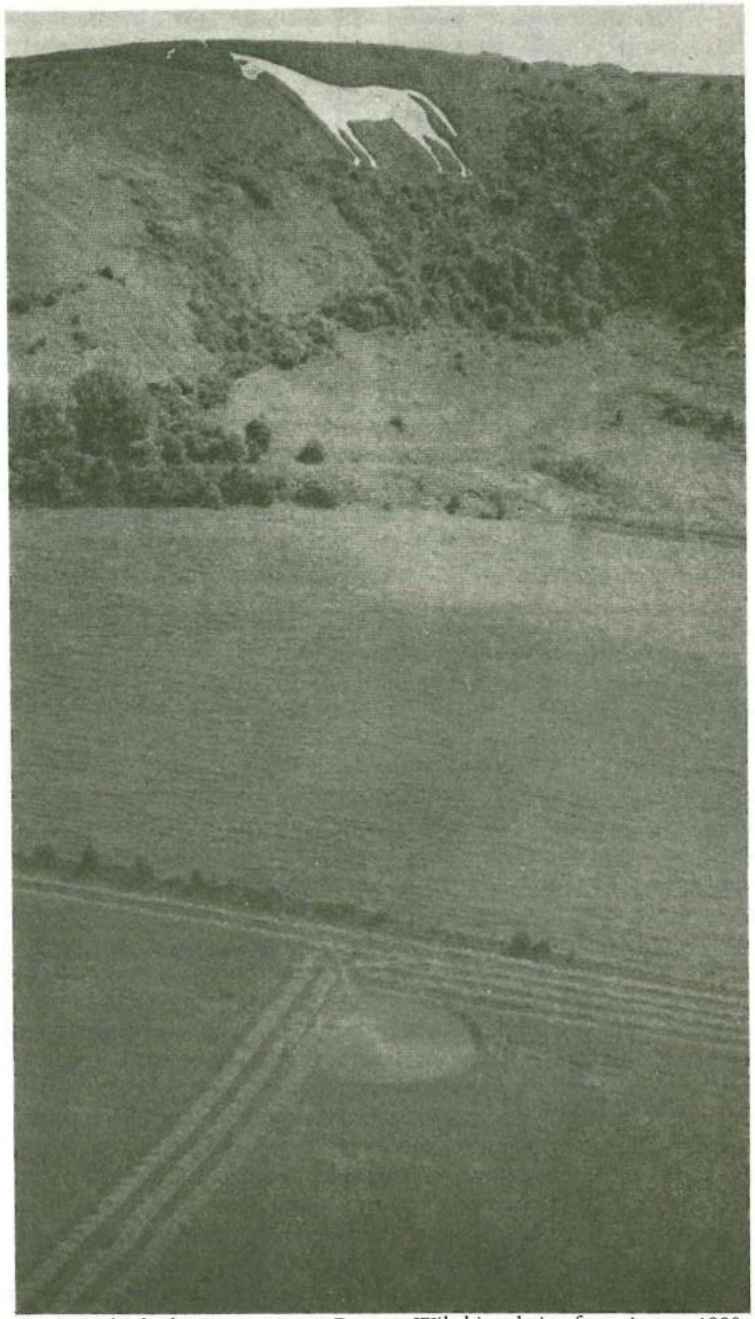

Fig.6: Multiple damage pattern at Bratton, Wiltshire, dating from August 1980.

related to the main vortex by time as well as space; they form as a consequence of the strength of the main one and occur while the main one is still going strong.

We suggest therefore that, when a major thermal is sustained in a typical dynamic state which is quasi-stationary relative to the ground and rotation about it then commences giving birth to a standing whirlwind, then the forces in the general inflowing circulation can be such as to stabilise minor whirlwinds in 2-fold or 4-fold symmetric positions about the major. The result of these complex forces is readily discernible in the damage patterns of the ripe or unripe cereals but less easily seen in very short crops or meadow grass.

Consequently, we predict that the patterns so far observed are simply part of a larger and more general scheme displaying multiple nodes, as suggested for instance in Figure 5(b). Systems based on 8-fold, 6-fold or 3-fold symmetry may be found in the future, and also systems in which satellite whirlwinds trace out arcs that link up with the main circle.

Next, one should consider briefly to what extent it is possible that a partial hoax may be involved. This author's answer is definitely not. I have inspected some fifteen circles. They all had the same characteristics which would be very difficult to reproduce (especially in near darkness), such as the perfect spiral radiating outwards from an often ex-centric point. Moreover, no-one but a whirlwind expert would ever know what the characteristics of authenticity are, and I doubt whether even he could successfully duplicate a natural example. It has been mentioned elsewhere that some of the aerial photographs of the 1983 Bratton set of circles (set 1) show that somebody has walked along some of the arcs of a hypothetical ex-circle which exscribes all four satellites. However it is probable that this unimportant track was made in the first week by one or two surveyors who were shown on an early T.V. film to be measuring out the circle sizes.

Lastly, it may be asked: why were there so many quintuplet circle sets in 1983 and none in 1980-1982? Well, there was the Cheesefoot Head triplet in 1981, but more importantly and, entirely unknown to us until 1983, there was a multiplet system at Bratton in 1980 after all. The evidence can be seen in the aerial photograph of Figure 6 first published on 29 August 1980 by *NOW!* magazine. The author had never seen this photograph and its accompanying article until Ian Mrzyglod discovered it in August 1983. We had all assumed that each of the first two Bratton circles of 1980 was a singlet circle, attended by some miscellaneous wind damage as commonly happens to many fields during a British summer. In fact, it is certain that the higher incidence of whirlwind circles, complex or single, in 1983 was related to the weather whose critical factors (yet to be explored) were just right.

THE 1984 SEASON

Obviously the best investigative means of advancing our understanding of the origins of these spiral circle complexes is to be on hand (preferably with weather instruments) when the circles are being formed. To this end, the author will be cooperating with Ian Mrzyglod and colleagues to visit the Bratton, Westbury, Cley Hill, and Upton Scudamore sites at frequent intervals from May to August 1984 in the hope of witnessing such an event, or if not to arrive within 24 hours of an occurrence. We hope by this means to have a precise knowledge of the local

weather when the circles are being formed (wind direction and force, state of sky, sun, state of ground, temperature and humidity). We must point out, however, that due to crop rotation the same fields are not necessarily under cultivation each year. For example, the oat field in which the 1980 Bratton circles were formed was under grass in 1983. Nevertheless, it does appear that most fields in the localities of interest have been planted with crops this year, at least some of which will be bearing long wind-sensitive stalks from mid-May until harvest-time.

TORNADOS, DARK DAYS, ANOMALOUS PRECIPITATION AND RELATED WEATHER PHENOMENA

This unusual, rambling heading is the title of another excellent collection of curious accounts of uncommon weather phenomena which have been put together as a 196-page volume by Mr. William R. Corliss (The Source Book Project, P.O. Box 107, Glen Arm, MD 21057, U.S.A.; U.S. $11.95, 1983). Like its predecessors it is highly recommended to readers who (a) like to read lots of very short, true stories for their scientific entertainment value, or who (b) wish to ponder and try to understand just how those observations and phenomena came to take place. Mr. Corliss hopes by this means to induce learned scientists to apply their talents to the lesser known, very perplexing problems in the natural sciences.

In order to provide a good flavour of the scope of this work, we are giving numerous extracts from primarily just one section of this present volume (namely 'falls', as defined below), followed by a few examples of point rainfalls (in view of recent articles in this journal). The other sections are most interesting and thought-provoking too. Surprisingly, the problem of mysterious circles or tracks in fields did not feature in this volume, so presumably the subject has been planned for a future volume in the series.

GWF. FALLS

GWF0. INTRODUCTION

Anomalous rain, snow, and hail are treated in the next chapter. Beyond these 'nearly normal' forms of precipitation are those falling materials that do not belong aloft at all: large chunks of ice, living animals, non-meteoric stones, and many other nominally terrestrial materials. Charles Fort made much of falling materials,

even though most of them can be explained rationally by appealing to recognised meteorological mechanisms; i.e., whirlwinds, waterspouts, tornados, etc. Fort did have a point, however, any small minority of falling material not succumbing to convential explanations would require truly revolutionary explanations. Such is the claim of residual anomalies in all areas of science – and this claim is perfectly valid in this chapter.

The overwhelming majority of falls consist of terrestrially derived material and earth-dwelling animals. So-called sulphur falls almost invariably turn out to be wind-blown pollen. The sensationalised falls of fish and frogs, which are well-verified in the literature, are easily explained in terms of whirlwinds, waterspouts, and tornados. Immense falls of hay, leaves and insects, though startling, are scarcely anomalous. Nature provides ready sources of such material as well as natural vacuum cleaners to snatch up light-weight objects and deposit them somewhere else. Even so, these types of falls present some enigmatic aspects: (1) The descent of some species of animals is so overwhelming in quantity that scientists are hard-pressed to explain where they could have all been collected; (2) The 'purity' of the falls; that is, the absence of coexisting species and debris from the falling animals' habitat.

Falls of cobwebs and the so-called gelatinous meteors (or 'pwdre ser') introduce a more unsettling factor. While admitting the reality of ballooning spiders, it seems that some of the great web falls involve a substance that may not be insect-produced – it is too strong and quickly evaporates away. It also falls in strands hundreds, even thousands of feet long. Some gelatinous meteors, too, seem to evaporate away strangely. If these properties can be verified, we have something more anomalous than a simple fish fall.

Another pair of phenomena with related characteristics will conclude this introduction: the large hydrometeors and the much-maligned thunderstone. Both phenomena typically occur during thunderstorms. A peal of thunder rings out and something strikes the ground nearby. If one finds a large chunk of ice, a passing plane can always be blamed; but if one finds a stone or even a meteor emotional disbelief takes charge. Yet, no physical reason bars the fall of meteorites during thunderstorms, nor can one deny the possibility of a strong whirlwind picking up a stone of several pounds weight and releasing it during a thunderstorm. After all some large hailstones reach several pounds, too. The point here is that the possibility of stonefalls should not be dismissed out-of-hand because of any innate distrust of legends carried over from ancient times.

The data presented below show rather conclusively that odd things do fall from the sky on occasion. Regardless of the sensationalism usually attached to these falls, most of them are not really very anomalous. A rain of frogs may be rare and certainly Fortean, but meteorology is well-equipped to deal with most aspects of this phenomenon.

GWF1. ICE FALLS OR HYDROMETEORS

Description. Chunks of ice that fall from the sky that are substantially larger than the largest recognised hailstones; that is, more than five inches in diameter or weighing more than 2 pounds. The ice pieces may fall from a clear sky or they may descend after a powerful stroke of lightning. The chunks may be clear ice, or

layered structures, or aggregations of small hailstones. This diversity of structure and meteorological conditions suggests that ice falls may have several different origins.

Background. Today, the fall of large ice chunks is usually blamed on aircraft passing over-head. Certainly, aircraft constitute a likely source, but there are many pre-Wright examples of this phenomenon. Furthermore, aircraft can be ruled out in some modern cases. Nevertheless, it seems that most people are satisfied with the aircraft explanation – perhaps because other origins are difficult to imagine.

Data Evaluation. Some of the older data may seem apocryphal (viz., XI), but there are so many modern ice falls, some investigated by meteorologists, that no one can deny that large ice chunks do fall from the sky on occasion. Rating: 1.

Anomaly Evaluation. Given the fact of ice falls, it seems that large ice chunks weigh so much that the prevailing theory of hail formation in storm cells is inadequate to explain them. The vertical winds in hailstorms do not seem powerful enough to support the large pieces of ice under discussion here. In fact, some modern ice falls are so large that the customary 'aircraft' explanation would seem to be wanting. Rating: 2.

Possible Explanations. (1) The vertical winds in storm cells are much stronger than generally recognised; (2) Some unappreciated mechanism in hailstorms permits the sudden aggregatation of many hailstones; (3) Those hydrometeors that fall after severe lightning strokes may be formed in the lightning discharge channels, possibly as a result of electrostatic forces; (4) Some ice chunks may be true meteors, i.e., from outer space. This last explanation has been ridiculed in the past but some meteorologists are now seriously proposing it, noting in passing that Saturn's rings may be composed of ice chunks.

Similar and Related Phenomena. The fall of meteor-like objects during thunderstorms (GWF2); giant snowflakes (GWP2); giant hailstones (GWP5).

(Here follow 51 cases).

GWF2. STONE FALLS

Description. The fall of stones, singly or en masse, larger than the coarsest sand carried by strong winds, say, more than ¼ inch in diameter. Most stone falls are recorded during powerful thunderstorms, usually in conjunction with loud peals of thunder. Some stone-falls are meteoric in character; that is, a luminous streak is observed. The stones recovered, however, are almost always of terrestrial origin.

Background. Such observations are the basis of the discredited thunderstone belief. Many ancient peoples believed that lightning and thunder were accompanied by a missile, often shaped like an axe head, that was hurled by some supernatural agency. So strong is scientific antipathy towards these supernatural overtones that stone-fall reports are usually rejected with contempt regardless of their merits.

Data Evaluation. Stone-fall data are weak. Almost all testimonial. These data are gathered under stressful conditions that encourage distortion and exaggeration. Other phenomena, such as ball lightning and ordinary meteors, have similar characteristics, thus confusing the situation. Finally, it is always difficult to be sure that recovered stones are not just indigenous rocks that happened to be in the area where the phenomenon occurred. Rating 3.

Anomaly Evaluation. Two kinds of anomaly may be present here: (1) If the fallen stones are terrestrial in origin and have been picked up by small whirlwinds, the weights of the stones infer higher vertical wind velocity components than generally allowed in thunderstorms; and (2) If the stones are meteoric and fall preferentially during thunderstorms, a cause-and-effect relationship is inferred. Rating: 2.

Possible Explanation. (1) The stones are simply wind-levitated terrestrial objects dropped during thunderstorms; (2) They are meteorites that just happen to fall during thunderstorms; (3) The supposed fallen stones never actually fell and are indigenous to the area.

Similar and Related Phenomena. The similarity of stone-fall and ice-fall characteristics cannot be ignored; both are often accompanied by loud claps of thunder and are frequently much larger than current meteorological theories permit. Ball lightning may closely emulate stone-fall phenomena. See also 'terrestrial' meteorites (AY).

(Here follow 26 examples)

GWF7. GELATINOUS METEORS OR PWDRE SER

Description. The fall of gelatinous masses, usually accompanied by luminous phenomena. The substance is soft and jelly-like, odiferous, and has a tendency to evaporate away rapidly. Gelatinous meteors range from a few inches to four feet in diameter according to reports.

Background. The idea that offensive masses of jelly-like substance can fall from the sky is firmly entrenched in folklore, as confirmed by many colourful names, such as pwdre ser (a Welsh term, more correctly spelled *pwdr ser*), star shot, rot of the stars, etc. In the examples that follow, the reader will find two different phenomena confused: (1) The observed fall of something from the heavens; and (2) The discovery in fields of gelatinous masses. The latter phenomenon possesses a simple biological explanation – assuming the mass did not fall. The actual fall of jelly-like substances admits to no easy solution, assuming its reality.

Data Evaluation. With few exceptions, the observations of gelatinous meteors in flight are old and rather shaky. Many examples proffered as cases of gelatinous meteors are weakened by the strong possibility of misidentification and coincidence; that is, one sees a luminous body descend nearby, searches the next morning, discovers a gelatinous mass in the general direction of the visual phenomenon, and calls it a gelatinous meteor. Meteor impact points are easily misjudged, and natural gelatinous masses seem rather common in fields. Nevertheless, many cases cannot be eliminated easily, and there is much internal consistency. Rating 3.

Anomaly Evaluation. The confirmed descent of gelatinous masses from outer space would constitute a significant anomaly, for (quite obviously) they do not fall into any recognised class of meteorites. Rating 2.

Possible Explanations. Most so-called gelatinous meteors are likely terrestrially produced substances, such as plasmodia, decaying fungi, water-swollen and distorted animal remains, and even man-made substances. True gelatinous meteors can not be explained.

Similar and Related Phenomena. Animal falls (GWF10-14), biological matter in meteorites (ER).

(Here follow 24 cases).

GWF10. FISH FALLS

Description. The fall of fish from the sky, often by the thousands, and usually along with heavy downpours. With rare exceptions, the fish are native to the area and alive when they hit the ground, roofs, and other structures. However, falls of dead, decaying, and dry fish have been reported. Fallen fish average 2-4 inches in length, although specimens up to a foot are on record. The area of a fish fall is typically long and narrow – a hundred feet to several miles in length.

Background. Fish falls have long been ridiculed by the scientific world and debunkers of strange phenomena, even though perfectly reasonable meteorological mechanisms exist for levitating fish and transporting them long distances.

Data Evaluation. Most reports of fish 'falls' are really announcements that fish have been found out of their element; viz. on dry land or isolated pools of water. Observations of fish in free fall are rare. Nevertheless, the circumstantial evidence is very strong in many instances and when combined with the high-quality accounts of people seeing fish in the air and even being hit by them makes a strong case for the reality of the phenomenon. Rating: 1.

Anomaly Evaluation. Whirlwinds, waterspouts, and tornados can all pick up surface-swimming fish and deposit them at a distance. The anomalous features of fish falls are: (1) the falls of dead, decaying, frozen, and dry fish; and (2) the selectivity of most falls; i.e., one species only and no debris. These are not serious anomalies. Rating: 3.

Possible Explanations. Whirlwinds, waterspouts, and tornados probably account for most fish falls. Even dead and decaying fish along a shore may be picked up and transported. Some instances of supposed fish falls may result from the temporary overflowing of fish-containing bodies of water and the release of fish buried in the mud.

Similar and Related Phenomena. All other falls of living animals, especially frogs and toads (GWF11).

(79 examples then follow).

GWF11. FALLS OF FROGS AND TOADS

Description. The descent of frogs or toads from the sky, usually by the hundreds or thousands. Frog and toad falls are inevitably associated with heavy summer rainstorms. The falling animals are usually alive, although some die upon impact, and average about a half inch in length. These falls are generally 'pure'; that is, not accompanied by other aquatic species or plant debris.

Data Evaluation. Rather surprisingly, many very good cases of frog/toad falls are on record, although they tend to be concentrated in the Nineteenth Century, when science openly discussed such events without fear of ridicule. While the bulk of the cases involve animals actually seen in flight, some reports may be due to population explosions and mass migrations, with no actual levitation involved. Rating: 1.

Anomaly Evaluation. As in the case of fish falls (GWF10), whirlwinds, waterspouts, and tornados are believable meteorological mechansims for collecting and transporting small frogs and toads. The anomalous features of this phenomenon are: (1) The very large number of individuals involved, which infers that the levitating mechanism must strip very large areas of toad/frog habitat and then concentrate its cargo; (2) The selectivity of the phenomenon; i.e., the general lack of debris and other species typical of the animals' habitat. Rating 3.

Possible Explanations. The conventional explanation – whirlwinds, waterspouts, tornados – seems the only reasonable one at this time.

Similar and Related Phenomena. The other animals falls in this section, particularly fish falls (GWF10).

(38 examples, of which we reproduce the following).

X9. June 1833. – Jouy, France. "I saw toads falling from the sky; they struck my umbrella; I saw them hopping on the pavement, during about 10 minutes in which time the drops of water were not more numerous than the toads. The space upon which I saw the multitude of these animals was about 200 fathoms." (W. L. McAtee, *Monthly Weather Review,* U.S., *45,* 217, 1917).

X14. Summer 1846. – Humber River, England. Frogs fell on vessels in the river and the coast near Killinghome lights. *loc. cit.*

X13. 1844. – Selby, England. "In the course of the afternoon of Monday last, during the prevalence of rather heavy rain, the good people of Selby were astonished at a remarkable phenomenon. It was rendered forcibly apparent, that with the descent of the rain, there was a shower of another description, viz., a shower of frogs. The truth of this was rendered more manifest by the circumstance that several of the frogs were caught in their descent by holding out hats for that purpose. They were about the size of a horse-bean, and remarkably lively after their aerial but wingless flight. The same phenomenon was observed in the immediate neighbourhood. *Zoologist, 2,* 677 (1844).

X23. Circa 1891. – Bournemouth, England. "One day we had a violent thunderstorm. Having no shelter, I was wet to the skin in a few minutes, and saw small yellow frogs, about the size of a florin or half-crown, dashed on the ground all around me. I ran to shelter under a large mortar-pan, and, after the storm was over, found in this pan hundreds of these small frogs . . . Thousands were impaled in the furze bushes on the common close by, and days afterwards the stench from the decomposing bodies was very noticeable." F. S. Hinder, *English Mechanic, 94,* 62 (1911).

GWF14. FALLS OF MISCELLANEOUS LIVING ANIMALS

Description. Falls of living animals other than those described in earlier sections. Included here are purported falls of shellfish, snails, snakes, lizards, and similar reptiles and amphibians. As with the other reported animal falls, the miscellaneous falls are generally concurrent with heavy rainfall. Very large numbers of individuals may be involved. These falls usually consist of one species only, with no accompanying debris.

Background. Heavy precipitation may drive terrestrial animals out of their hiding places and, in other instances, stimulate population explosion of mass movements. Most humans have little appreciation for the immense number of animals living hidden around them. Thus, when a storm drives these creatures abroad in great numbers, anomalous falls from the sky are claimed erroneously.

Data Evaluation. Most reports of animal falls recorded below are suspect because the animals were not actually seen in flight. The evidence for a 'fall' is therefore circumstantial. A few cases are rather convincing (X1, X2, X6, X7); and these generally involve water-dwelling species. Composite rating: 2.

Anomaly Evaluation. The best cases, which include water-dwelling animals, yield readily to the usual whirlwind-waterspout-tornado explanation. It is curious though how shellfish, for example, are separated so cleanly from the sand in which they live. The weakest cases concern rather large animals, snakes, turtles, etc., and would require very strong winds to whisk them aloft. The puzzling aspects here are minor, and a composite rating of 3 is all that is justified. Rating: 3.

Possible Explanations. The familiar trio: whirlwinds, waterspouts, and tornados.

(18 cases, of which two are reproduced here).

X6. June 6, 1869. – Chester, Pennsylvania. "Mr. John Ford exhibited to the Conchological Section, Academy of National Sciences, Philadelphia, specimens of *Gemma gemma,* remarkable as having fallen, accompanied by rain, in a storm which occurred in Chester, Pennsylvania, on the afternoon of June 6, 1869. The specimens were perfect, but very minute, measuring one-eighth inch in length by three-sixteenth of an inch in breadth. Though most of the specimens which fell were broken, yet many perfect ones were collected in various places, sheltered from the heavy rain which followed their descent. A witness of the storm, Mr. Y. S. Walter, editor of the *Delaware County Republican,* assured Mr. F. that he noticed the singular character of the storm at its very commencement, and to use his own words, "it seemed like a storm within a storm." A very fine rain fell rapidly, veiled by the shells, which fell slower and with a whirling motion. Judging from the remains of animal matter attached to some of the specimens, together with the fresh appearance of the epidermis, it is highly probable that many of them were living at the moment of transition. This minute species resembles a quahaug shell, and is common on the sea-shore between tide marks." *Monthly Weather Review, U.S., 5,* p.8, (1877).

X7. August 9, 1892. – Paderhorn, Germany. "A yellowish cloud attracted the attention of several people, both from its colour and the rapidity of its motion, when suddenly it burst, a torrential rain fell with a rattling sound, and immediately afterwards the pavement was found to be covered with hundreds of mussels." The mussels were still alive and were identified as *Anodonta anatina L. Nature, 47,* p.278 (1893).

SOME EXAMPLES OF POINT PRECIPITATION (From GWP12)

X5. 1849. – Alpine, Georgia. "A Water Spout, of immense size, the 2nd inst., near Alpine, Chattanooga county, Ga. It is said to have made an impression in the earth thirty feet deep, and forty or fifty feet wide, and that it eradicated the largest forest trees, and removed rocks weighing several thousand pounds. *Scientific American, 4,* p.414 (1849).

X6. May 3, 1849. – Bredon Hill, England. An enormous body of water rushed down a gully doing considerable damage. "The course of the torrent could easily be traced up the hill for more than a mile, to a barley field of five acres, the greater part of which was beaten down flat and hard, as if an enormous body of water had been suddenly poured out upon it. Beyond this there were no signs of the fall of water to any great amount." *Nature, 125,* p.657 (1930).

X7. August 1864. – Nevada. "I was travelling from Humboldt mines to Reeves river. The whole country was dry and parched, as is usual at that season of the year, and the weather was even warmer than common. About 2 o'clock p.m. I saw what appeared to be a whirlwind. It appeared to be about 25 miles distant, and the spiral column extended from the earth to a very dense cloud, which was nearly as high as the scattered mountains in that vicinity. Soon this column seemed to break, the upper third of it being detached from the rest and bent over to the eastward. I then perceived that this spiral column was not of dust, as I had first supposed, but was water. The next day I crossed a canon leading from the place where the phenomenon had occurred. Water was still running in it, and there was evidence of a recent flood. Inquiring further, I consulted the Hon. William R. Harrison, a gentleman of scientific attainment who had spent several years in the Humboldt mountains. He told me that such phenomena were not of infrequent occurrence in the Humboldt mountains, and were called 'cloud-bursts.' He had witnessed several of them – had once been in the edge of one, and had once stood on the top of a mountain and witnessed the terrific scene in the canon beneath him. He says: 'The first sign of them is the sudden gathering of a small, dense, black cloud on the mountain side, about one-third of the way from the top, and generally at the head of a canon. Soon this cloud seems to dash itself to the earth, taking a circular motion. It appeared as if an inverted whirlwind was drawing from the cloud immense quantities of water, which is dashed in floods against the mountain side'." W. J. Young. *Smithsonian Institution Annual Report,* 1867, p.471.

X17. August 1, 1932. – London, England. "It began to rain – heavily at first and then softly. Suddenly torrential rain fell only one hundred yards from where I was standing. The nearest trees in Kensington Gardens were almost hidden behind a milky mist of heavy rain. The rain-drops rebounding off the street created a layer of spray as high as the tops of the wheels of the taxis standing in the street. Where I was sheltering, hardly a drop of rain was falling. The contrast was so striking that I called the attention of an unknown bystander (as though I could not believe my eyes). Then the spray on the ground came nearer like a wave, and receded. Suddenly it vanished completely, and the trees behind in Kensington Gardens stood out black against the sky. It was over." G. A. Hinkson, *Met. Mag., 67,* p.159 (1932).

X18. August 2, 1966. – Greenfield, New Hampshire. "Rain began to fall about 1900 EST, or about an hour before the outbreak of more generalised showers in the region. It soon became a downpour, continuing until about 2300 EST, at which time Mr. Stanley went to bed. It was then still raining, but had slackened noticeably. The rain may have stopped by midnight. A remarkable nonvariability of the intense rain was noted by Mr. Stanley. There was very little slackening, even for brief intervals, during the period of heaviest fall, which was from about 1945 to 2215 EST. There was practically no wind. Neither thunder nor lightning was observed. The noise on the roof was terrific, like that of a continuous waterfall. A plastic bird feeder mounted on the side of the house was broken by the impact of sheets of water from the eaves. Looking

out the window, Mr. Stanley could see stones and gravel from the roadway, south of the house, being washed away by torrents of water. Upon rising in the morning, Mr. Stanley noted that the weather had cleared, with a brisk westerly wind. After finding the 5.75 in. of rain in the gauge, he inquired from a neighbour 0.3 mi to the east. He found that the neighbour had but 0.50 in. in his gauge. He there-upon examined the countryside for visible effects. The road washout extended only a few hundred feet. Upon going one-half mile in either direction, no evidence of rain erosion of sand or gravel could be found. South of the house, beginning at the gauge which was mounted on a pole, well distant from structures or trees, there stretches a 10-acre field. The knee-high grass therein was beaten down flat. By afternoon it began to revive. By the following noon it was erect. To the west of the house, a dry-wash brook running bankful at dawn was empty by 0800 EST. Drawing a line around the traces of erosion, one obtains an oval area about a mile north-south and about three-fourths of a mile east-west. Within this area, rain varied from the order of 1 in. on the limits to almost 6 in. in the centre. Outside this limit, rain is believed to have fallen off sharply to less than one-fourth of an inch generally within a few thousand feet." *Monthly Weather Review, 98,* p.164 (1970).

THE KIBO LEOPARD

I was interested in Michael Hunt's reference to the mummified corpse of a leopard on the Kibo summit of Kilimanjaro (*J. Meteorology,* p.42, Feb.1984). This was found by Dr. Reusch, D.D., in a notch in the glacier rim on the north-east side some years prior to the last war. It is now marked on the map as Leopard Notch or

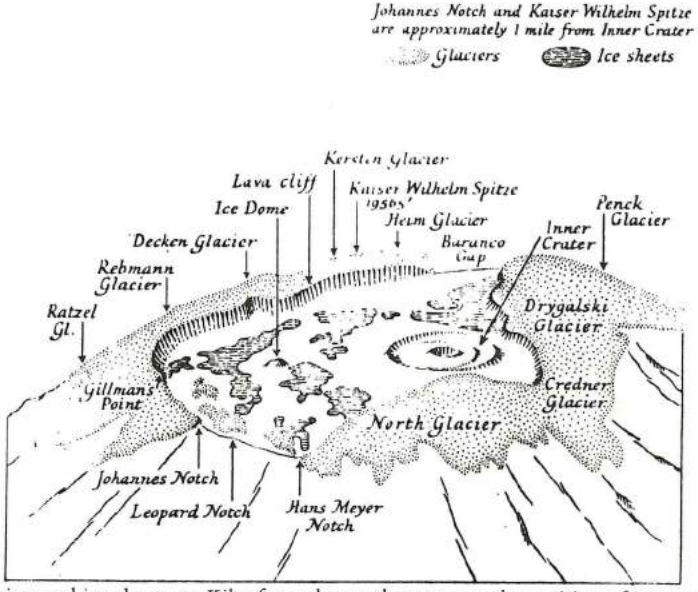

Fig.1: Glaciers and ice-sheets on Kibo from the north-east; note the position of Leopard Notch.

Point (Fig.1). The accompanying photograph of the leopard carcase (Fig.2) dates from the late 1930's and was taken by Mr. P. R. C. Baily.

I was informed that corpses of animals can be discovered at high altitudes because some sick animals instinctively go higher for rarified air when in a dying condition. I was told of an antelope which had been discovered high on Mt. Kenya, also mummified. I personally noted dead butterflies at around the 5,800 m contour on the snow surface of the Rebmann glacier on Kibo in 1943, but this was due to anabatic wind elements from the hot plains surrounding the massif.

Fig.2: Photograph of the leopard carcase, from below.

As Mr. Hunt remarks, the recession of the glaciers on Kibo is not due to an increase in fumarolic activity but is due to a very considerable climatic change over the past few thousand years, in fact since the last Pluvial (Pleistocene) period which was responsible for many of E. African lake levels being over 100 m above their present levels (as Nilsson points out in his *Glaciations and pluvial lakes in British East Africa* [1932]). At the same time the glaciers of both Kilimanjaro and Mt. Kenya descended to much lower levels; on Kibo to the 3,600-3,900 m contours, and even lower in the Ruwenzoris. On Mt. Kenya I have walked on moraines covered with bamboo forest as low as the 2,700 m contour.

Thornton Hall, Ulceby, South Humberside. P. C. SPINK

LETTERS TO THE EDITOR

BRITAIN'S LOWEST ANNUAL RAINFALL TOTALS

Looking through past editions of *British Rainfall, The Meteorological Year Book* and the *Annual Weather Reports* I have noticed the following. The lowest annual rainfall total on record for England is not the 9.29 inches at Margate in 1921 as is popularly supposed, because as little as 7.94 inches was recorded on the Isle of Grain in Margate for the same year.

Other notable low annual totals of rainfall in England in other years have been 11.68 inches at Stretham in Essex in 1870, 12.01 inches at Chatteris in Cambridgeshire in 1884, 12.78 inches at Sleaford in Lincolnshire in 1887, 11.86 inches at Chatteris in 1901 and 11.10 inches at Wickham Bishops in Essex in 1933. However the lowest annual total rainfall for Wales is as high as 15.64 inches at Monmouth in 1921. The lowest annual rainfall total on record for Scotland is 11.79 inches at

Dunnethead in Caithness in 1870. In 1911 Kilmany in Fifeshire recorded only 14.50 inches. St. Abbs Head in Berwickshire had only 14.11 inches of rain in 1955. Kinloss in Invernesshire received as little as 13.07 inches of rain in 1973. The lowest annual rainfall total for Ireland is 14.04 inches at Glasnevin in Dublin in 1887.

22 Holly Bush Lane, Amblecote, Stourbridge. A.MACLEAN

[It is true that the 7.94 inches (201.7 mm) on the Isle of Grain in 1921 is likely to be the lowest annual total ever 'measured' in the U.K. but because conditions of measurement were non-standard, the reading was never officially recognised. Indeed, some small suspicion is also attached to the 1921 Margate reading of 9.29 inches/235 mm, despite the following affirmation on page 148 of *British Rainfall 1921* ". . . the official record at Margate gives only 9.29 in, and there is no reason to regard it as inaccurate, the station having been specially inspected and found to be in good condition." But what is nevertheless peculiar is that in another part of the *same* region of Margate (namely Cliftonville), but at 37 metres above sea-level compared with 16 metres, the 1921 rainfall total was 11.64 inches/296 mm, i.e. 25% higher! Furthermore, there were 110 days with significant rain at the latter compared with 95 at the former. One is therefore led to wonder whether some kind of systematic error existed; for instance, did the observer habitually hold the (metric!) measuring cylinder at an angle? The next lowest 1921 rainfall totals came from nearby Ramsgate; these were 10.73 inches (273 mm) and 10.93 inches (278 mm) – Ed.]

THUNDERSTORMS AND A TORNADO IN THE YORKSHIRE COUNTIES ON 14 JANUARY 1984

A very active cold front crossed the region during the morning and produced frequent lightning, thunder, hail and, in the Doncaster area, a tornado. During the late morning and afternoon, gales gusted to force 9 and 10 as a deep depression crossed northern Britain.

The writer was first awoken by thunder and heavy rain at about 0630 GMT; the wind was southerly and moderate. Lightning became more frequent with a rate of one stroke every 1 to 3 minutes and discharges to ground within a kilometre. A sudden veer of wind direction to fresh-to-strong westerly was accompanied by a short but heavy fall of rice-sized hail and a rapid drop in temperature. When the front had passed the Leeds area earlier, disruptions had been caused by the lightning, and ball lightning was reported, but the most severe effects of the cold front passage were experienced by people living in the Bessacarr and Cantley suburbs of Doncaster. A report in the *Sheffield Morning Telegraph* indicated that 131 houses were damaged, some severely, and several brick-built garages were totally destroyed. Four people were injured but none seriously. The initial, estimated, damage cost was put at around £500,000. Eye witnesses described how things were seen 'flying around in the air' and with a noise 'like an express train thundering through the house'.

Fig.1: One of the buildings destroyed in the Doncaster tornado – a council greenhouse at Bessacarr.

The borough chart at Cawood (Wistow Mine) indicated the classic 'kick' upwards in pressure at the passage of the cold front. The further fall and later rise in pressure was during the period of gales which hampered members of the fire and other services who attempted to sheet-over damaged roofs at Doncaster and elsewhere.

There can be little doubt that the Doncaster tornado was associated with the passage of a very active cold front.

Manor Garth, Riccall, Yorkshire. David V. RANDON

WEST AFRICAN DROUGHT WEAKENS MIGRANT SWALLOWS

Despite the excellent weather in Britain and France in the last half of April, Britain's migrant swallows arrived later and were fewer in number this year than in any spring this century. According to the British Trust for Ornithology (whose headquarters are at Tring, Hertfordshire), the reason lay far off in West Africa which had just had its lowest winter rainfall for 90 years. This meant that the numerous birds of passage, such as swallows, house martins, swifts and warblers, were unable to obtain sufficient food in order to fly across the wider-than-ever Sahara Desert. Such migrants pass the winter in the south of the African continent and the summer in Europe. They replenish their body reserves on their long flight north by resting in tropical West Africa. Unfortunately, two years of winter drought in traditional resting places such as the Senegal Valley have parched the usual wet lands and denied the migrant birds the chance to eat and refuel properly.

LATE EASTER BROUGHT GOOD WEATHER

In 1984 Western Europe had its best Easter holiday weather for many years. Most of Britain was completely dry for the four days Friday 20 to Monday 23 April, with much sunshine and considerable warmth. Highest temperature was 26.2 °C (79.2 °F), at St. Helier, Jersey, which equalled or exceeded the U.K. record for this date (Bawtry and Cambridge had 79 °F on 22 April 1901).

From the weather viewpoint it was helpful that Easter came so late this year. The date of Easter Sunday (22 April) was three days from its latest possible date of 25 April (upon which it will fall in the year 2038). The earliest date for Easter Sunday is 23 March (this will next happen in 2008). The last warm Easter Sunday was in 1979 when it fell on 14 April and temperatures above 20 °C were widespread (22.2 °C at Trowbridge).

TORRO TORNADO REPORT: September 1983

The weather settled down to a more normal pattern in September 1983. One tornado was reported, the lowest total for September since 1979 (when there were none).

TN1983September15. *Quernmore, Lancashire (SD 509598-518602).*

This tornado occurred in a showery airstream in the circulation of a depression centred over southern Scotland (980 mb at 1800 GMT). Some of the showers were heavy, and a few were thundery in northern and eastern England. At 500 mb a low was centred just off N.W. Ireland.

The tornado at Quernmore, near Lancaster, was reported by the *Lancashire Evening Post* of 16 September and the *Lancaster Guardian* of 16 and 23 September. The principal witnesses, Mr. John Drinkwater and Miss Mitton, also kindly supplied information.

The first damage was at Conder Mill Farm (SD 509598), where John and Will Drinkwater saw branches being ripped from a tree and thrown 15 metres into the air. The tornado then struck the farm and the brothers ran into a farm building, the roof of which was then torn off. Another building was lifted bodily into the air, and the roof of another was raised and then dropped out of place. John Drinkwater said: "We could see the whirlwind disappearing. Clouds were right down to the ground, and they were whirling round." In a letter to TORRO he added that the path width was about 50 metres. Force was T3.

Quernmore C. of E. Primary School, about 1 km to the N.E. (518602), was also struck, and minor damage was done. The headmistress, Miss Audrey Mitton, gave the time as 1300 GMT (as did Mr. Drinkwater).

In his letter Mr. Drinkwater mentioned the following additional damage:

Askew Hill, SD 524612 (trees); Heights Farm, 531623 (unspecified); and Ravenscar Farm, 544632 (new building). The first two places are in line with the known track of the tornado. It is possible that the tornado was triggered at least partly by the topography, because it followed the fairly deep, narrow valley of the River Conder.

On the afternoon of 19 September Mr. J. Diaper, of Fulbourn, Cambridgeshire (TL 5256), experienced "an extremely strong and very localised gust of wind, which was strong enough to lift off our garage roof asphalt, which was very heavy. The cloud that caused it was relatively small; it was not accompanied by any thunder, but around the edge of the cloud there was a large amount of rapid swirling, but the swirling did not descend from the cloud". It is possible that this was a case of a tornado with an invisible funnel.

Addition to reports for October and November 1982: Mr. J. A. R. Henry was at Ryeland (NS 652397), near Caldermill, Strathclyde, when he saw a funnel cloud which apparently reached the ground. It lasted about 5 to 10 minutes before withdrawing into the clouds. The date was late October or early November.

Addition to report for May 1983: Mr. Rex Hutchison observed and photographed a tornado while fishing on Carron Valley Reservoir, Central Region, on 7 May 1983. The tornado was at NS 6883. Showers and thunderstorms were widespread in Scotland on this date. When Mr. Hutchison later met his friends who had been fishing about 1 km north of where he saw the tornado, they said that they had experienced such heavy rain that they had had to bail out their boat; no rain fell where Mr. Hutchison was. It is quite possible that the heavy rain was really water levitated by the tornado as it crossed the reservoir.

M. W. ROWE, G. T. MEADEN

TORRO THUNDERSTORM REPORT: July 1983

By KEITH O. MORTIMORE
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July was a hot, sunny month and the very high temperatures were responsible for local thunderstorm development on numerous days in many parts of the U.K. and Eire. Thunder was heard somewhere on 5th-14th, 16th-19th, 21st-27th and 31st; just one day more than the normal. The most thundery area of Great Britain was central England with 10 days at Birmingham University and Hinckley in Leicestershire, with six to eight days in many other inland parts of England, and with four to six days quite widely in the south-east. In Belgium there was thunder on 5th-9th, 12th, 17th-19th, 23rd, 24th, 26th-28th and 31st, exceeding the normal by four days; at Mont Rigi there was thunder on nine days and seven at Mettet and Houwaart. In the Netherlands there were seven thunder-days at Ten Post. In West Germany thunder was heard on 1st, 5th-8th, 11th, 16th, 18th, 19th, 24th, 25th and 29th; there were five days at Frankfurt and seven at Munchen-Reim.

The first thunder of July occurred on 5th when, after a hot mostly cloud-free day, continental thunderstorms drifted north into parts of south-east England by midnight and to other parts of southern England and East Anglia during the early hours of 6th. After a quiet morning with only very isolated thundery outbreaks a thundery low moved into the British Isles from the continent in the afternoon, setting off heavy storms in many parts of southern England and Wales and to a lesser extent in northern England, Northern Ireland and around the Firth of Forth in Scotland. Rainfall was locally very heavy with 94.8 mm at Ide Hill, near Sevenoaks, in Kent and 75 mm at Kew Gardens. Hail also fell in places. A man died after being struck by lightning on Barnes Common and another was badly injured at Northampton. Very isolated storms persisted into the early hours but generally it was a rainless, close and sticky night with a good deal of fog. The fog thinned and cleared during the morning of 7th but with the shallow low still slow-moving over central England rapidly rising temperatures set off further thunderstorms over England, Wales and southern Scotland, particularly over higher ground, but they died away quickly in the evening. After another humid, close night with widespread fog, the 8th was again hot and sunny but this led to afternoon thunderstorms in the hottest parts of southern England, and over the high ground of Wales and Northumberland. There were also scattered, quite severe storms over the mountains of Scotland. During the afternoon of 9th there were scattered storms in western Scotland, and at midnight there was thundery activity in the Scilly Isles. Convergence ahead of a slow-moving frontal zone to the south-west of Britain set off further thunderstorms on 10th. Activity was confined to the far west of Cornwall in the early hours but, as the day progressed, storms developed more widely, spreading north or north-west across other parts of south-west England, south Wales and Eire and accompanied by marked pressure fluctuations and gusty winds in places. These areas continued to be affected by scattered thunderstorms through the early hours of 11th, although activity had declined considerably by dawn, but later, hot sunshine regenerated thunderstorms in Cornwall, south Wales and southern Eire. In the afternoon and evening there were more over the Welsh hills and in the Cairngorm area of Scotland. Apart from scattered thundery outbreaks in southern and central parts of Eire early on 12th, most parts of Britain had a very hot day with much sunshine but later in the afternoon and in the evening thundery showers and thunderstorms developed over some of the northern hills of England and Scotland. In Angus, Scotland, there were widespread power cuts, and lightning caused considerable havoc in Eire. A number of homes in a Co. Dublin suburb were extensively damaged by fire after being struck by lightning, and property was damaged in some other areas. Very high temperatures again set off local thunderstorms on 13th, this time in parts of Wales and western England, and on 14th parts of central and southern England were similarly affected.

The 16th was sunny and hot over England and Wales as far north as Lancashire and West Yorkshire and, as on so many days so far, there were thunderstorms later in the afternoon in Wales and in some central and western areas of England. During a storm at Heswall on Merseyside there were some 15 lightning discharges per minute for at least 30 minutes. Scattered thunderstorms continued to affect Eire, Wales and western and northern counties of England during early hours of

17th, and during the day they became more widespread and severe with a tornado at Allenhead in Northumberland. In southern England it was a hot day with isolated heavy thunderstorms. Large hailstones shattered car windscreens in the Exeter area and stones up to 10 mm in diameter were still lying some two-and-a-half hours after a storm in the Goyt Valley near Buxton in the Peak District. Around 58 mm of rain fell near Pickering (N. Yorkshire) with 68 mm in 45 minutes at Saxthorpe between Aylsham and Cromer (Norflok). Storms in the Lake District were also severe and a walker was killed by lightning at Easedale, while at a farm near Harrogate a 17-year-old girl strawberry-picker was taken to hospital after being struck by lightning. At the American air-force base at Fairford (Gloucestershire) a police Chief Inspector was seen to be enveloped in a haze of blue light after a lightning flash. At Quarley, near Andover two horses in a field were killed by a lightning discharge that gorged 10 cm-deep furrows in the ground, and at Barton-le-Willows, between York and Malton, six cows worth £700 each were killed beneath an oak tree; trees and building were damaged in many parts of the affected area and power disruptions were reported widely. Heavy rain caused flooding in many parts. A cold front moved slowly south-east across England and Wales on 18th but central areas of England and Wales were still very warm and humid and scattered thunderstorms developed in the afternoon and early evening over parts of the Midlands and East Anglia. Following the clearance of the cold front and with pressure building to the west, the 19th was a drier, fresher day everywhere but there were a few scattered showers in eastern parts of central-southern England with an occasional clap of thunder in the late afternoon. With an anticyclone over central Britain the 21st was a glorious summer day but thundery conditions were developing around a low over northern Spain and late in the evening thunderstorms with heavy rain reached the Channel Islands and Cornwall. In the early hours of 22nd storms moved north-east across Devon, south Wales and into the extreme south-east of Eire, and during the course of the day frequent thunderstorms spread to many parts of Wales and England. By late evening they had reached as far north as Manchester and south Yorkshire, with only isolated activity further north, and in places, particularly in central-southern England and the west Midlands, storms, mostly high-level, continued right through the following night. A severe storm left a trail of destruction in parts of north Wiltshire. The church spire at Hilperton, Trowbridge, was badly damaged by lightning, together with a house only a few hundred metres away, and homes were struck in Chippenham. Bales of straw were set alight at Allington and Bishop's Cannings (Wiltshire), a cow was killed at Potterne, and the Marlborough Library was hit by lightning leaving a stone pinnacle precariously balanced above the High Street. A house at Orpington (Kent) was also damaged by lightning. Thunderstorms continued to affect central and south-eastern areas of England well into the morning of 23rd, with further outbreaks in north Wales and the north Midlands in the evening and in east Kent around midnight. Northern Ireland and Eire also had thunderstorms during the day. The 24th was storm-free at first, apart from early activity in east Kent, but later in the morning heavy showers and thunderstorms developed in central and southern England moving north into northern Scotland in the evening. The rain was very heavy with some 25 mm in an hour in places. There were also thunderstorms locally in Northern

Ireland and Eire in the evening. In the afternoon of 25th thunderstorms moved northwards across northern Cumbria and Scotland as far north as Inverness but quickly died out again in the evening. Rainfall of extreme intensity would seem to have fallen in a remote part of the Hermitage area of Borders, near Newcastleton. After a river burst its banks a wall of water nearly seven metres high and 200 metres wide in places surged across two to three kilometres of countryside leaving a trail of destruction. About 100 sheep were killed, three bridges were seriously damaged, sections of road were ripped up and trees uprooted. At Old Gorrenberry part of a hillside was washed away. About 70 mm of rain fell in one hour at Boreland but it can be safely assumed that a much larger quantity fell very locally in the catchment area of Hermitage Water. Early on 26th there were scattered thunderstorms in the extreme south-east of England, on the edge of a large storm area moving north-east into the Low Countries, and in the early evening isolated storms developed over mid-Wales and the northern Midlands, and later over parts of Wiltshire and Oxfordshire. Thunderstorms in the south-west Midlands persisted until after daybreak on 27th with some heavy rain over the Cotswolds and adjacent areas.

With a cold front moving south-east across north-western Britain and a low moving north-east over northern France, many parts of England and Wales had thunderstorms on 31st. After early thundery showers in the Channel Islands thunderstorms broke out over much of the south-west in the morning and they became widespread over England and Wales in the afternoon and evening before the cold front brought a clearance into northern and western areas by midnight. Some of the storms were severe with heavy rain and squally winds, and there was a tornado at Ivybridge (Devon). At Guernsey in the Channel Islands the following observations are of particular interest – *1300 GMT.* Wind: 100°/23 kt, temperature: 17 °C, dew point: 17 °C; *1330 GMT.* Wind. 200°/28 kt, temperature: 30 °C, dew point: 02 °C; *1400 GMT.* Wind: 090°/09 kt, temperature: 24 °C, dew point: 14 °C. The relative humidity at 1330 GMT was 16 percent – a record low for the Island. There was a pressure fall of 6 mb in 15 minutes, an aircraft fell 3,000 feet from 5,000 feet near the Island and the wind gusted to 63 kt. A pressure fall of 4 mb in five minutes was also recorded in the London area. Rainfall was very heavy in places with 65.9 mm at R.A.F. Cranwell (near Sleaford in south Lincolnshire).

WORLD WEATHER DISASTERS: February 1984

1: M.v. *Thomas K* sank in storm-lashed seas 21 km south of Iro Zaki lighthouse, Izu Peninsula, Honshu, Japan, leaving one dead and seven missing. *Lloyds List.*

1-29: Widespread and serious monsoon floods in Indonesia, worst of floods in Java, on the 3rd, at least seven rivers in Purbalingga and Banyumas provinces in flood, with some 10,000 people evacuated; by the 6th floods began to recede in some areas of island, but serious floods developed in East Java; by 10th serious fllods in West Java; on the 15th floods in East Java reported as worstin 50 years, at least 676,000 hectares of land inundated and devastated, also on this day a landslide in district of Ciamis, some 125 km south-east of Bandung in West Java destroyed 46 homes and damaged 388 others, no casualties. Floods hit other

areas of Indonesia, on the 4th floods up to 5 metres deep in South Kalimantan, left ten villages under water. Rains on the 7th touched off landslide in Manado, North Sulawesi, leaving 3 dead. Heavy rains touched off serious floods in Ujungpandang, South Sulawesi on the 10th. On the 26th heavy rains touched off landslide in Simalungun district, North Sumatra, hitting a small village leaving 25 dead. During month floods and landslides in affected areas of Indonesia left 48 dead and some 1,370,000 hectares flooded, with 62,000 hectares severely damaged. *Jakarta Post.*

2: M.v. *Apollonia V.* sank off Algiers, Algeria, during bad weather, leaving three missing. *L.L.*

2-17: Heavy rains and serious floods in northern, north-eastern and eastern provinces of Sri Lanka, some 700,000 people made homeless, about 40,000 homes damaged and rail and road transport disrupted, at least two deaths reported. *Daily Telegraph, L.L.*

4: Storm hit area of Paso de Los Toros, Durazno Department, Uruguay, with 100 km/h winds which uprooted trees and brought down power and telephone lines, roofs blown off buildings in rural areas, storm hit between 1400 and 1530 hours, lightning accompanying storm left one dead and one injured. *L.L.*

4-6: Serious forest fires around Valparaiso, Chile, several houses destroyed, 'dozens' of firefighters and residents treated for burns and effects of smoke. *L.L.*

4-6: Blizzard in U.S. Mid-West and Eastern states, worst of blizzard in North Dakota and Minnesota, which were hit on the 4th, where winds gusted to 100 km/h; by the 6th snow moved into southern and eastern states, in northern Georgia up to 100 mm of snow fell with a similar amount in northern Alabama, in western North Carolina up to 150 mm of snow fell, lesser amounts of snow in other eastern states, at least 28 direct or indirect deaths attributed to storm. *International Herald Tribune, L.L.*

5: High winds and rain over Brecon Beacons, Mid-Wales, left one soldier dead of exposure. *D.T.*

6-8: Gales and high winds in many parts of Great Britain, winds up to 120 km/h recorded throughout England, Scotland and Wales, many trees uprooted and many buildings damaged on the 6th/7th, in Scotland gales accompanied by heavy snow, which blocked over 30 major roads, three died when car hit lorry near Tain, Ross-shire, floods in areas of Wales, West Country and Midlands; on the 8th fierce gales, gusting to 130 km/h, hit southern England, 50 trees, all 250 years old, uprooted in Savernake Forest, near Marlborough, Wiltshire, widespread damage to property in West Country, Kent, Sussex and Surrey, chimney fell through roof of house in Rita Road, Lambeth, London, killing one person; over a dozen tornados in the early hours of the 8th. *Birmingham Evening Mail, D.T.*

6 (reported): Cyclone, described as worst for ten years, hit port of Magadan, eastern U.S.S.R., for four days, causing widespread damage, storm moved into the Sea of Okhotsk through the Bay of Nagaeva. *L.L.*

7: M.v. *Midnight Sun 1* sank in storm on 7th, some 13 km north-west of the island of Ushant, Brittany, France, leaving 8 dead. Gales across France, with blizzards in the Alps. 50 buildings in Corps (Isère) lost roofs on 8th at 1430. *Le Dauphiné.*

Fig.1: Une église à Champ-prèsFroges au Grésivaudan (près de Grenoble) qui a perdu sa toiture pendant le tempête de 8. A Corps 50 bâtiments ont perdu lours toitures.

7-10: Gales, rainstorms and snowstorms hit south and west areas of West Germany, winds gusted to 260 km/h across high ground in Bavaria, many trees uprooted and buildings damaged, the torrential rains caused river levels to rise and touched off serious floods; rivers Rhine, Main, Moselle, Necker, Lahn and Dill overflowed causing widespread damage towns of Dillenburg and Herborn, in state of Hesse, hit by worst floods since 1946. In North Rhine Westphalia, cities of Aachen and Siegen hit by floods described as worst since 1891. Low-lying areas of Bonn and Cologne flooded, by the 10th river levels were dropping, damage put at millions of dolloars, three indirect deaths reported during storms and floods. *L.L.*

7-10: Heavy snow, followed by avalanches, in many areas of Switzerland, roads and mountain passes blocked. About 35 avalanches occurred in almost all mountainous areas of Switzerland, particularly in the Grisons, Uri and Valais regions. Damage estimated at over $10,000,000. At least seven deaths reported, four of them in Saumen, Grissons Canton, on the 9th. *L.L.*

8: River Rimac overflowed in central Peru after heavy rains, a 1.5 km stretch of highway washed away along with 20 houses in Huachipa, 20 km east of Lima, no casualties, some 2,000 vehicles stranded on the highway. *L.L.*

8: Avalanche at Millinocket, Maine, U.S.A., left 2 dead, 2 injured. *B.E.M.*

10-14: Fierce blizzards in Hungary and Yugoslavia.

Hungary: Southern part of country hit by blizzards described as some of the worst this century, with winds of 100 km/h reported in Bekes county on Feb. 11th-12th, blizzards followed by cold, at least 4 died in blizzard.

Yugoslavia: Hit by five days of blizzards and cold, at least 11 deaths reported in severest winter in country for years. Drifts up to 3 metres deep in Vojvodina. By 14th worst of weather over but in north-west Slovenia, winds still gusted to 200 km/h. *I.H.T., L.L.*

11-15: Torrential rain, hailstorms and tornados in U.S.A., states from Texas to Alabama affected. Nearly two dozen tornadoes swept from south-east Texas and Alabama. Tornadoes uprooted trees, brought down power lines, ripped roofs from houses and tipped over dozens of trailer homes throughout southern

Louisiana. more tornadoes in Mississippi and Alabama. Winds up to 153 km/h hit south-east Texas and north-west Louisiana. Torrential rains, up to 130 mm of rain in a few hours, flooded areas in Louisiana and Mississippi. All the above occurred on Feb. 11th/12th. On the 15th, heavy thunderstorms, with golf-ball sized hail, reported in eastern Texas. In report-period 55 aircraft sustained hail damage at Dallas/Fort Worth airport, only a few injuries in storms. *L.L.*

12-14: Heavy rains touched off floods in various areas of Uruguay, roads cut, 500 left homeless. *L.L.*

17-18: Cyclone *Imboa* hit south-east Africa, worst effects were from heavy rains, Natal province of South Africa badly hit, with extensive damage and at least four dead, area was recovering from cyclone *Domoina* when new storm hit. *L.L.*

19: Avalanche near Valtournanche, Italy, left four dead. *D.T.*

19: Strong winds in Scotland, one gust blew man to his death off ridge on Coire an Sneachda, in the Cairngorms. *D.T.*

21: Tug *Eduard,* towing large barge with cranes aboard, sank in stormy seas some 30 km north of Ushant, Brittany, France, leaving six dead, later the barge sank near Lannion, Brittany. *L.L.*

22 (reported): Drought and famine in Mozambique has reportedly left 100,000 dead in recent months. *I.H.T.*

24 (reported): Blizzards and avalanches in the northern Indian states of Kashmir and Himachal Pradesh and in the Pakistan section of Kashmir left at least 30 dead and 20 injured. *D.T.*

25-28: Blizzards hit wide areas of U.S.A., storm originated in Colorado on 25th/26th and settled over the Mid-West and spread snow and rain from Great Lakes to the Gulf coast, at end of period snow, sleet and freezing rain hit north-east areas. Up to 230 mm of snow fell in northern Ohio. Rain, high winds and tornadoes hit eastern Gulf coast areas. Heaviest snow-fall reported from North Tonawanda, north of Buffalo, New York where 800 mm fell. At least 52 direct or indirect deaths attributed to storm. *L.L.*

26: Avalanches in France and Italy, at least five died in France, while in northern Italy four died, with another five reported missing. *D.T.*

26: Thunderstorms hit Bahrain breaking a record 319-day drought, the previous longest dry spell since records began in 1902 was 287 days between 1965 and 1966. *D.T.*

26: Avalanche on Carnedd Dafydd, above Ogwen Valley, Gwynedd, Wales, left two dead, two injured. *D.T.*

26-27: Thunderstorms and floods west of Roma, Italy, widespread damage, but no casualties. *B.B.C. Television News.*

29 (reported): Winter storms in Sistan province, Iran, have left at least 107 dead, with six others missing, worst-hit areas near Zahedan, area hit by 145 km/h winds and flooding; 300 injured people being treated in towns of Zahedan and Zabol, over 20,000 head of cattle also dead. *L.L.*

29-March 1: Cyclone *Chloe* hit Western Australia with winds up to 225 km/h after sweeping in from Indian Ocean, towns of Roebuck and Wickham reported severe damage to houses, port operations disrupted by cyclone, no casualties. *L.L.*

ALBERT J. THOMAS

MARCH 1984 WEATHER SUMMARY

March was a rather cold month and the lack of warm spring days resulted in mean maxima up to 1.5 degrees C below the normal in many parts of the British Isles and between 2.0 and 2.5 deg. below in parts of England and Wales. Mean minima were nearer the normal, ranging from a little above in some central and eastern areas of England and Scotland to as much as 1.5 deg. below in parts of the west. Highest temperature occurred during the first week with 16.1 °C at the Lizard and 15.0° at Plymouth on 5th, 15.3° at Yatton and Congresbury in Avon on 6th, and 15.2° at Liphook in Hampshire on 1st. In eastern Scotland 14.1 °C was recorded at Dyce (Aberdeen) on 4th and in Wales 14.9° was reached at Penmaen on 6th. The month's warmest nights were also recorded during this spell with 9.1° minima at Plymouth and in central London and 8.6° at Shide (Isle of Wight), all on 6th. Minima were in the region of 7° or 8° in the Western Isles of Scotland on 6th and 8.3° was reported from Stornoway on 4th. High Bradfield in south Yorkshire recorded the lowest known maximum of the month with −0.9 °C on both 17th and 18th and Lerwick (Shetland) recorded 0.9° on 1st. Other low values included 1.4 °C at Braemar on 26th, and 1.5° at Fylingdales on 2nd, 17th and 19th, with the same figure at Emley Moor (near Huddersfield) on 13th and at Bingley and Emley Moor on 18th. Exton on Exmoor recorded only 1.9° on 15th. Air frost was recorded somewhere on 30 nights and ground frost on every night, although on a number of occasions freezing temperatures were confined to northern Britain. Apart from −4.7° at Bastreet (Cornwall) on 9th lowest minima occurred in the second-half of the month. Tummel Bridge in Scotland was the coldest spot with −8.4° on 18th, followed closely on the same night by Braemar with −7.6°. Scotland was also very cold on the previous night (17th) with −5° to −7° in many central areas. Over England −4.7 °C was recorded at Liphook on 21st and −4.8° at Elmdon (Birmingham) on 22nd. On the grass −12.9° was recorded at Glenlee on 16th, −12.1° at Edinburgh on 19th and −11.5° at Straide (Co. Mayo) on 17th. There were marked variations in rainfall percentages over the U.K. Many western and northern areas were dry, particularly adjacent to the Bristol Channel where only 30 to 40 percent was recorded in places, but it was wetter in the east with 125 to 150 percent. It was particularly wet in parts of eastern and north-east England with some 200 to 250 percent. The highest reported 24-hour total was 50.6 mm at Long Kesh (Co. Down) on 23rd with 40.0 mm at Bessbrook on the same day. The 23rd, incidently, was a very wet day over much of Ireland, England and Wales with few areas recording less than 25 mm to 30 mm. Other high totals were 49.4 mm at Braemar and 38.4 mm at Glenlivet, both on 24th, 33.1 mm at Lerwick and 33.0 mm at Whalsay on 1st, and 28.9 mm at St. Helier, Jersey and 25.5 mm at Guernsey on 31st. Apart from Cornwall where sunshine totals were just above the normal, it was a very dull month with little more than 35 percent in the east Midlands and inland East Anglia. The Western and Northern Isles of Scotland fared somewhat better with more than 80 percent.

The first three days of March saw a small but rapidly-deepening low crossing the far north of Scotland and plunging south-eastwards down the North Sea into Europe. After early rain, very cold northerly winds, reaching gale force at times, carried snow and hail showers to most parts of Britain. During 4th a warm front

spread rain and much milder conditions from the west, but in the south falls were insignificant. Between 5th and 9th an anticyclone moved north-east into western Britain and intensified to a central pressure of 1045 mb by 8th before slipping away again to the south-west, whence it came. This was a rather cloudy high with just enough breaks to produce some frost and a little fog at night, and after a mild start temperatures by day steadily fell to below normal. A depression moved south across the North Sea on 10th, and on 11th another moved south across the British Isles making the latter a wet, unpleasant day with rain or wintry showers in most parts and even some local thunder. With low pressure becoming established over the Iberian Peninsula and with a large high-pressure area developing well to the north the following week was cold and very disagreable with raw north-east winds and with some light showers of rain, sleet or snow at times. There was generally a lot of cloud but a few clearer spells led to locally higher temperatures by day but at the expense of frost and fog at night. The 21st brought early signs of a change of weather type as a cold front moved into north-western areas from the Atlantic, and over the next few days a deep complex depression to the south-west spread a good deal of rain to all areas, especially on 23rd/24th as a small low developed over southern Britain and moved away to the north and then north-west. On 25th and 26th, with the parent low moving slowly north across England and Wales, all areas continued to have further spells of rain, much of it falling over southern Scotland and northern and eastern England, and there was some snow over higher ground. By 29th the low had moved away into Denmark but the latter days of the month continued to be very unsettled and cold, with showers or longer spells of rain, sleet or snow and with local thunder, and later on 31st a front moving north into the south-west produced snowfall accumulation above about 150 metres.

K. O. M.

TEMPERATURE AND RAINFALL: MARCH 1984

	Mean				*Grass*					
	Max	*Min*	*Max*	*Min*	*Min*	*Rain*	*%*	*Wettest*	*D*	*T*
BELGIUM: Uccle	8.0	1.1	11.8(23)	-2.4(10)		49.3		11.5(2)	14	-
„ Rochefort	8.6	-3.3	13.4(22)	-8.6(10)		43.6		11.0(2)	12	-
„ Houwaart	9.4	-1.8	13.9(21)	-7.2(21)	-8.0(21)	39.3	67	6.7(2)	14	1
DENMARK: Fanø	3.9	-0.3	7.6(5)	-3.2(9)		49.4	117	12.2(3)	14	0
„ Frederikssund	4.3	-2.2	11.1(29)	-8.2(19)	-9.5(19)	21.7	65	7.2(28)	13	0
GERMANY: Berlin	6.7	-0.8	16.1(29)	-5.3(20)	-7.0(20)	10.1	33	4.7(2)	8	1
„ Hamburg	6.4	-0.9	12.4(29)	-5.7(9)	-8.6(9)	25.1	66	8.6(2)	9	1
„ Frankfurt	8.9	-0.6	13.8(24)	-6.5(11)	-9.8(10)	21.2	59	6.7(27)	8	2
„ Munchen	6.5	-3.5	17.6(28)	-9.7(9)	-15.7(9)	22.5	44	6.8(7)	8	0
„ Sonthofen	3.9	-2.2	16.3(28)	-12.3(10)		62.8		16.9(30)	13	1
ITALY: Casalecchio	12.5	2.5	20.0(25)	-2.0(11)		125.7	256	64.5(1)	9	1
MALTA: Luqa	16.4	9.3	21.6(28)	5.2(13)	1.2(13)	44.2		15.9(8)	10	4
NETH'DS: Ten Post	6.7	0.7	12.4(26)	-4.4(20)	-7.5(9)	54.5	120	10.3(3)	13	1
„ Schettens										
„ De Bilt										
NORWAY: Donski	2.4	-5.3	9.4(6)	-12.8(4)		30.8		14.3(29)	12	0
SWEDEN: Valla	2.1	-5.2	8.2(6)	-14.9(24)		10.5		6.3(29)	13	0
SWITZER'ND: Basel	9.4	-0.7	16.7(28)	-6.4(11)		24.1	50	5.5(24)	10	1
EIRE: Galway	9.2	3.1	13.0(5)	-0.2(19)		40.2	46	19.4(23)	16	1
„ Straide	9.0	1.7	12.7(5)	-4.5(17)	-11.5(17)	56.3	79	14.0(23)	14	0

	Mean				*Grass*					
	Max	*Min*	*Max*	*Min*	*Min*	*Rain*	*%*	*Wettest*	*D*	*T*
N.IRE'D: Bessbrook	7.8	1.6	12.8(5)	-2.8(16)		74.9	97	40.0(23)	16	1
SHETL'D: Whalsay	5.4	1.7	8.6(5)	-2.2(1)	-4.4(8)	85.3	135	33.0(1)	21	0
„ Fair Isle	5.2	2.5	7.9(4)	-0.1(1)	-5.0(8)	46.6	62	16.5(1)	23	0
SCOTL'D: Braemar	4.7	-0.8	9.8(4)	-7.6(18)	-8.3(18)	142.5		49.4(24)	16	0
„ Stirling Univ.	7.7	1.6	12.9(6)	-3.2(17)		70.6		25.9(24)	16	-
WALES: Moel-y-Crio	6.0	0.7	12.0(5)	-1.7(16)	-4.2(22)	58.5	108	14.4(23)	14	0
„ Pembroke										
„ Gower	8.8	2.7	14.9(6)	-1.6(16)	-6.5(17)	19.0	24	4.4(23)	9	1
GUERNSEY: Airport	8.2	4.2	11.7(5)	2.2(9)		83.0		25.5(31)	11	0
ENGLAND:										
Denbury, *Devon*	8.9	1.4	13.3(5)	-2.7(22)	-7.5(20)	80.1	93	31.2(23)	12	0
Gurney Slade, *Somerset*	7.4	0.5	13.5(6)	-3.3(30)	-5.1(30)	53.2	56	23.2(23)	13	0
Yatton, *Avon*	9.0	2.0	15.3(6)	-1.8(30)	-4.6(30)	44.1	78	22.7(23)	12	0
Congresbury, *Avon*	9.0	2.6	15.3(6)	-0.3(30)		46.8		22.0(33)	11	0
Trowbridge, *Wiltshire*	8.4	1.7	14.6(6)	-1.8(30)	-6.7(30)	45.5	95	22.2(23)	12	1
Codford, *Wiltshire*	8.4	0.4	12.1(1)	-4.1(21)	-6.4(21)	61.2	73	31.0(23)	11	-
Corsham, *Wiltshire*	8.1	1.9	13.9(6)	-0.5(30)		43.0		19.6(23)	14	1
Marlborough, *Wiltshire*	7.8	0.7	13.1(6)	-2.3(21)		52.3	89	28.4(23)	14	0
Reading, *Berkshire*										
Sandhurst, *Berkshire*	8.9	1.4	14.4(1)	-2.8(19)	-8.3(19)	83.9	193	28.1(23)	14	1
Newport, *Isle of Wight*	9.0	3.0	13.2(1)	-1.2(21)	-3.2(4)	85.3	119	21.3(23)	13	0
Horsham, *Sussex*	9.0	2.0	13.5(1)	-1.5(4)	-6.0(9)	92.6	189	29.0(22)	12	2
Brighton, *Sussex*	8.8	2.3	12.0(6)	-1.0(4)	-2.5(4)	78.0		18.1(23)	12	1
Hastings, *Sussex*	7.6	2.4	10.9(5)	-0.3(9)	-4.0(1)	74.5	149	20.2(28)		2
Dover, *Kent*	8.3	2.2	13.1(23)	-1.9(1)		81.0	175	20.0(28)	15	1
East Malling, *Kent*	8.4	2.3	12.7(23)	-1.6(10)	-7.0(4)	59.4	138	17.1(23)	14	1
Epsom Downs, *Surrey*	8.4	1.8	12.2(23)	-4.2(19)	-6.2(19)	87.5	117	29.7(23)	13	2
Reigate, *Surrey*	8.0	3.2	13.4(30)	-1.5(19)		71.3	137	21.7(23)	12	0
Guildford, *Surrey*	8.6	2.5	12.4(1)	-1.3(19)	-4.5(19)	93.8	158	27.4(23)	11	1
Hayes, *London*	8.4	2.0	13.5(6)	-2.2(3)	-5.6(3)	78.4	199	23.0(23)	13	1
Hampstead, *London*	7.8	2.3	13.0(1)	0.0(22)	-4.6(30)	65.7	156	17.5(23)	13	2
Sidcup, *London*	8.8	2.6	13.2(23)	-1.6(4)	-7.6(-)	59.8	131	16.9(23)	13	1
Royston, *Hertfordshire*	8.0	2.1	12.5(6)	-0.5(8)	-5.1(8)	38.7	89	12.7(23)	15	0
Loughton, *Essex*	7.8	1.0	12.5(6)	-3.2(30)	-7.4(30)	52.0	80	15.3(23)	12	1
Leigh-on-Sea, *Essex*	8.6	2.3	12.5(23)	-1.0(4)	-4.0(4)	42.7	86	8.8(23)	14	0
Pulham St.Mary, *N'folk*	7.8	1.7	11.9(5)	-2.7(4)	-6.2(4)	43.8	110	9.0(23)	15	2
Buxton, *Norfolk*	7.9	2.1	11.5(23)	-3.6(21)	-4.4(21)	75.2	161	9.7(23)	14	0
Scole, *Norfolk*	8.1	1.8	11.9(5)	-2.5(4)	-7.6(4)	40.5	101	11.5(23)	14	2
Ely, *Cambridgeshire*	7.9	0.9	11.7(23)	-1.5(3)	-4.1(4)	33.1	68	4.9(23)	16	1
Luton, *Bedfordshire*	7.7	1.8	12.5(1)	-2.4(30)	-6.6(4)	64.7	143	24.1(23)	13	1
Bedford, *Bedfordshire*	8.0	1.8	12.8(6)	-1.9(30)	-6.1(30)	43.9		12.1(23)	13	0
Buckingham, *Bucks*	7.5	1.4	12.1(6)	-1.6(30)	-6.0(30)	43.4	101	12.6(23)	12	1
Oxford University	8.3	2.4	13.0(1)	-0.3(19)	-5.2(4)	50.3	125	19.6(23)	17	0
Stroud, *Gloucestershire*	8.2	2.6	12.8(6)	-0.6(30)	-2.8(22)	45.5	83	18.8(23)	14	1
Birmingham Univ'sity	7.2	1.8	11.2(6)	-2.1(22)	-6.0(22)	54.7	91	16.1(23)	16	0
Kettering, *Northants*	8.0	1.6	12.2(6)	-3.6(30)	-6.0(v)	42.9	85		15	0
Hinckley, *Leicestershire*	7.5	1.8	11.7(6)	-2.0(22)	-4.4(22)	64.1	128	15.6(23)	14	0
Cosby, *Leicestershire*	7.3	1.4	11.7(6)	-1.7(22)	-5.0(8)	60.0	126	13.5(23)	17	0
Louth, *Lincolnshire*	7.5	2.0	12.2(6)	-2.0(23)		55.9		11.8(23)	14	1
Newark, *Notts*	8.3	1.9	13.6(5)	-3.1(23)	-6.3(23)	56.6	120	17.7(24)	16	1
Nottingham, *Notts*	7.8	1.8	13.2(5)	-2.9(23)	-4.6(23)	72.2	166	15.7(24)	16	1
Middleton, *Derbyshire*	5.0	0.6	10.7(5)	-2.0(20)		64.4		16.3(24)	18	0
Burton-on-Trent, *Staffs*	7.9	3.7	12.6(5)	-0.4(9)	-7.0(9)	52.9	123	15.1(23)	19	0
Keele University, *Staffs*	6.7	1.3	10.6(5)	-1.6(16)	-5.7(16)	47.0	97	13.4(23)	13	1
Sefton Park, *Merseyside*	8.4	2.4	12.2(5)	-1.1(16)		37.7		8.6(25)	12	0
Lathom, *Merseyside*	7.4	2.1	11.1(27)	-0.8(15)		40.3		9.1(3)	13	-

	Mean Max	Mean Min	Max	Min	Grass Min	Rain	%	Wettest	D	T
Sheffield, *S.Yorkshire*	6.9	1.5	13.2(5)	-2.1(20)	-6.0(20)	60.1	80	20.2(23)	11	1
High Bradfield, *S.Yorks*	3.1	0.3	8.8(5)	-3.1(20)						
Cottingham, *Humber*	8.0	2.0	13.2(5)	-2.0(20)	-4.7(31)	65.3	121	15.2(22)	16	1
Pickering, *N.Yorkshire*	7.0	1.0	13.0(5)	-2.8(9)	-7.7(8)	78.5		22.2(24)	18	0
Carlton-in-Cleveland	6.6	1.6	11.6(5)	-2.5(22)	-5.1(22)	86.5		18.8(24)	20	0
Durham University	6.9	1.9	12.7(6)	-2.1(22)	-4.2(22)	52.2	116	12.0(24)	22	-
Sunderland, *Tyne/Wear*	6.5	3.1	12.8(6)	1.0(3)		69.6	163	20.0(24)	18	0
Carlisle, *Cumbria*	7.6	2.4	11.2(5)	-3.3(16)		44.7	78			
Kendal, *Cumbria*	8.5	2.4	14.0(5)	-2.5(3)		44.4	46			
CANADA: Halifax	1.9	-5.2	10.2(16)	-16.6(11)		140.3	120	29.8(19)	18	0
„ Pincourt, Que.	-1.5	-11.2	9.9(v)	-28.0(9)		38.3		9.9(13)	9	0
ANTARC: Noumeyer	-10.4	-17.7	-3.9(27)	-27.0(15)						
JAMAICA: Montego	29.4	21.4	33.3(29)	19.4(29)		32.4		12.0(8)	8	0
AUSTRIA: Innsbruck	9.4	-1.5	15.0(26)	-9.3(13)	31.9	73		29.0(11)	9	0

CORRECTION:
Birmingham University, *February* mean minimum +0.8 °C.

MARCH RAINFALL, CUMBRIA:
Honister, 139.0 mm; Seathwaite, 140.0 mm; The Nook, Thirlmere, 90.9 mm; Coniston, 78.2 mm; Appleby Castle, 53.9 mm.

APRIL RAINFALL, U.K.,
Preliminary Note:
A large part of southern England to the west of Hampshire and Oxfordshire received under 5% of its average rainfall in April: low totals included, 1.3 mm Boscombe Down, 1.1 mm Trowbridge, 0.8 mm Shide (Newport, Isle of Wight), 0.7 mm Brize Norton, 0.7 mm Hurn (Dorset), 0.6 mm Ilfracombe (N. Devon), 0.5 mm St. Catherine's Point (Isle of Wight), 0.5 mm Codford (Wiltshire), 0.3 mm Bournemouth (Dorset), 0.2 mm Totland Bay (Isle of Wight).
No rain was recorded at Tetbury (Gloucestershire), Bishops Cannings (near Devizes, Wiltshire), and Edington (near Westbury, Wiltshire).

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DAILY WEATHER SUMMARY

From 1 January 1984 the London Weather Centre has issued its *Daily Weather Summary* in a new format with improved clarity and appearance. Its numerous well-presented charts comprise the following:

Surface isobaric charts for western Europe for 0600, 1200, 1800, 2400 GMT, including frontal analysis and a simple weather description for many stations on the chart. The 1200 GMT chart extends across the whole North Atlantic.

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A copy of a satellite picture showing cloud patterns around the U.K. for each day.

There is also a monthly weather summary, based on the daily summary, and this includes mean pressure maps for the three ten-(or eleven) day periods in the month, and tables and maps of the mean monthly weather.

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JOURNAL OF METEOROLOGY Vol. 9, no. 89, May/June 1984

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FRONT COVER:
A summer day in Wiltshire, August 1980, showing the Westbury White Horse at Bratton and, in the foreground, whirlwind circles in a field of oats.

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