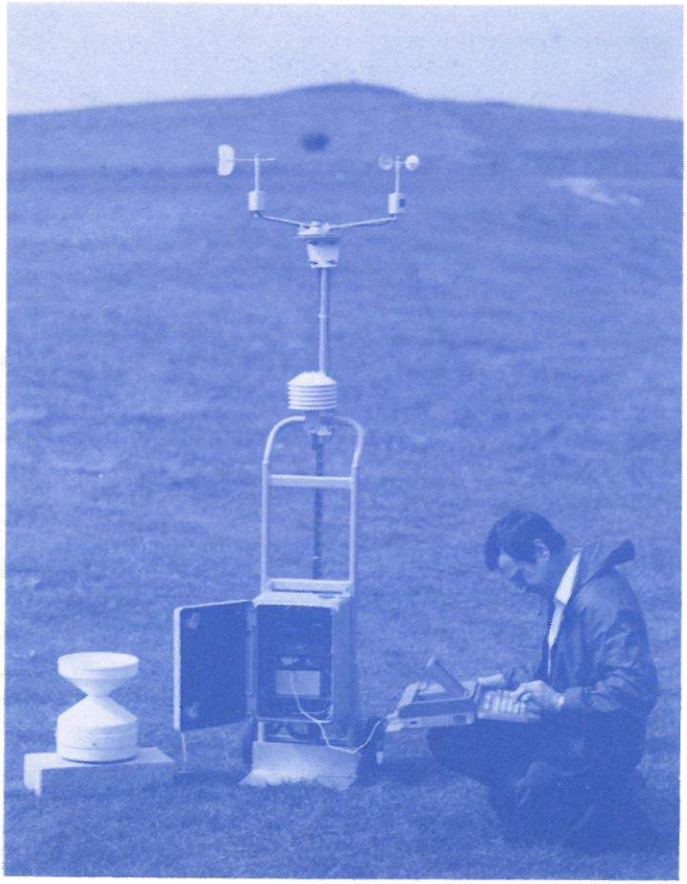
The JOURNAL of METEOROLOGY



THE SQUIRREL MINI-MET WEATHER STATION

Volume 13, number 134 **December 1988**

THE JOURNAL OF METEOROLOGY
LE JOURNAL DE MÉTÉOROLOGIE
Published in association with
The Tornado and Storm Research Organisation
a privately-supported research body, serving the national public interest
Edited by Dr. G. T. Meaden, 54 Frome Road,
Bradford-on-Avon, Wiltshire, BA15 1LD, England.
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Subscriptions for 1989, Volume 14, *including surface post,* U.K. £38.00; rest of world £44.00; *including airmail* £50.00. For personal subscriptions from individuals deduct £19.00 from each of these rates. Subscriptions for students and senior citizens £14.00 only upon request.

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Published by The Artetech Publishing Co., 54 Frome Road, Bradford-on-Avon, Wiltshire, BA15 1LD.

Printed by The Dowland Press Ltd., Frome, Somerset.

 ISSN 0307-5966

JOURNAL OF METEOROLOGY
"An international journal for everyone interested in climate and weather, and in their influence on man."
Editor: Dr. G. T. Meaden Vol. 13, no. 134, December 1988

THE POLAR LOW THAT LED TO WIDESPREAD SNOW AND THE EXTREMELY COLD CHRISTMAS OF 1860 IN BRITAIN

By W. S. PIKE
19, Inholmes Common, Woodlands St. Mary, Newbury, Berkshire.

Abstract: The cold Christmas of 1860 was caused by clear, anticyclonic weather following widespread snowfall primarily associated with a 'Polar Low' on 18-19 December, which was probably of the "deep convective spiral band, type 1c" (after Forbes and Lottes, 1985). Some cases of frostbite occurred, with freezing conditions lasting longer in Scotland where the bye-law then ordering urban householders to clear snow from the pavements is discussed.

Four surface synoptic charts covering the period 19-26 December are reconstructed, and the extensive frost overnight 24-25 December is mapped, when it is suggested that the record coldest night minimum for urban London (since accurate thermometry began around 1825) might well be held by Camden Square rather than by Greenwich. It is considered likely the familiar "4ft-high exposure" rule for thermometers recording air temperature, placed then on north-facing walls or in revolving ('Glaisher') stands, and today at 1.25 metres in Stevenson screens, could well have originated in the orderly mind of Sir George Airy at Greenwich.

Following criticism that Whistler was an "idle apprentice", and in response to noticing London's main arterial river freezing over, Whistler began painting "The Thames in Ice" on Christmas Day 1860 at Dagenham.

INTRODUCTION

The author was alerted to what must have been a very cold spell of London weather through chance viewing of an oil painting by James MacNeill Whistler (1834-1903) at The Freer Gallery of Art in Washington, D.C., U.S.A. Although titled "The Thames in Ice" (Figure 1), this picture had actually been painted over Christmas 1860 while the artist was working in London, according to brief notes in the Gallery which is part of the renowned Smithsonian Institution.

A quick inspection of Marshall (1952) confirmed that Whistler had indeed experienced some abnormally cold weather, because the lowest December night minimum in London during the past century was 8°F (–13°C) as recorded at the Royal Observatory, Greenwich, on Christmas Morning 1860 (p30). Early thoughts of Buchan (1861) and a recent investigation by Roach and Brownscombe (1984) indicate that many of the extremely cold temperatures below about –10°C recorded in Britain occur in clear, calm weather when dry, subsiding air arrives over a fresh snow cover (up to five days old). It was decided to look at the early telegraphic reports (archived at Bracknell Meteorological Office Library and commencing September 1860) plus private diary records (in Bracknell Archives) and old newspaper articles of the period (at the British Newspaper Library) in an attempt to reconstruct the weather leading up to Christmas 1860.

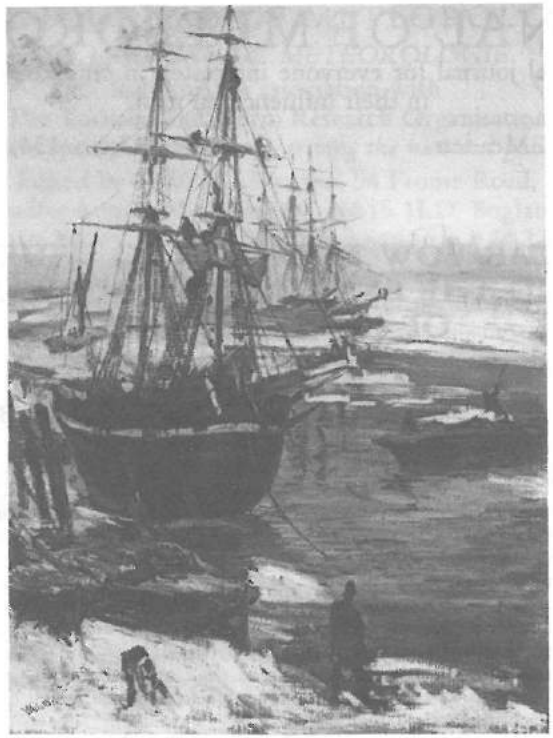

Fig.1: "The Thames in ice". An oil painting on canvas by James MacNeill Whistler (1834-1903) begun on Christmas Day 1860. 74.6cm x 55.3cm. Reproduced by courtesy of The Freer Gallery of Art, Smithsonian Institution, Washington, D.C. Accession No. 01-107.

POLAR LOW AND WIDESPREAD SNOW OF 18-19 DECEMBER 1860

After a mild and changeable first two weeks in December, without warning a cold northerly airstream became established over Northern Britain by early morning of Tuesday 18th; and heavy snowfall associated with a 'polar low' (Figure 2a) had commenced over much of Scotland by late evening that same day. The centre passed southwards down the east coast of Scotland, probably associated with a 'cold pool'; so entrained Arctic air passing over relatively warm waters of the North Sea resulted in deep convection. The inhabitants of Aberdeen were disturbed by thunderstorms lasting from soon after midnight until 3am on the 19th (a particularly violent one passing overhead awoke many around 2.30am according to *The Scotsman* of 22nd December. They found that 12-15 inches of snow (30-38cm) had accumulated in the streets by daylight. Falls were reported to similar depths in The Lothians and "up to 2ft deep" (60cm) in rural Fife. Further north, snow had not been so heavy, beyond Insch not exceeding 4-5 inches (12cm) and Elgin recording 3 inches (8cm) only. An editorial in *The Newcastle Chronicle* of Wednesday, 19th December read:

> "Snow fell more or less the whole of yesterday and a hard frost has set in. During last evening, the atmosphere was highly charged with electricity and frequent discharges were observed. Shortly after one o'clock this morning it commenced to thunder, and at the time we went to press* (*"probably around 3.00-4.00am" – Graham Stanton, today's *Evening Chronicle* Editor) the flashes were extremely vivid and frequent".

It is tempting to deduce that these thunderstorms were closely linked to the polar depression's passage southward, which may indeed be true, but it is also noted that thunder was subsequently reported from Berwick "later on Wednesday morning while snow was still falling" (*The Scotsman* of 22nd). A recent, if only partially-valid analogy from early winter occurred when English Channel thunderstorms associated with the 'Polar Low' of 8 December 1967 gave 11 inches (28cm) snow in Brighton and paralysed communications along the Sussex Coast particularly *between the Downs and the sea* (Stevenson, 1968).

Similarly on 19th December 1860, about 30cm of snow caused sudden delay and disruption to the Scottish railway system around Edinburgh, with severe problems as the snow began to drift, especially around Bathgate, and East Fife was cut-off completely. Published in Edinburgh, *The Scotsman* of 20th remarked on their "severe snow-storm":

> . . . "having commenced at about eleven o'clock on Tuesday night (it) has proved unprecedentedly heavy for the period of the year – such falls before Christmas being quite exceptional . . . During the whole of yesterday, snow and hail showers continued falling up till nearly six in the evening. The total depth may well be about twelve inches, but where drifted, it is double or treble that depth; and from the partial clearing of the pavements, by which of course, the carriage-ways are further encumbered, in some of the streets only a narrow line is left between the accumulated banks of snow. The house-tops and trees in gardens are thickly-covered, giving the town quite an Alpine aspect. One roof belonging to a horse dealer collapsed under the weight of snow, and a boy who happened to be in the place was rather severely though not dangerously cut on the head.
>
> The unwelcome pastime of 'snow-balling' has been enjoyed by numerous youths. At the University while the 'fun' was at its height. Professor Swinton, who we believe is convenor of the "Anti-snowball Association" came out among the students, and entreated them to disperse; but this appeal was only answered by shouts of laughter and a shower of snowballs from which the learned professor was speedily obliged to take shelter".

This rather long quote gives clear indication of how the Law at that time was generally felt to be asinine, and shows that youthful rebelliousness is not just a modern fashion. When faced with snow depths of 30cm or more, street clearing in towns simply overwhelmed police 'cleaning departments' who were also hampered by their own bye-law, a reminder of which was published on p.1 of the same edition of *The Scotsman:*

"The occupier of any house, tenant, warehouse, shop or other building within the limits of the act, shall once every day when necessary from the state of the weather before 10 o'clock in the forenoon, or oftener if necessary, cause the snow and ice to be removed from the foot pavement or footpath opposite to their respective premises; and every occupier who shall neglect to do so shall for every offence be liable to a penalty not exceeding forty shillings". (By order of the Office of Inspector of Cleaning).

But where was all the snow to go? This particular heavy fall might well have played its part, together with more-modern concepts of 'Public Safety' liability, in the eventual recession of this rather draconian bye-law. Certainly, the anger felt by many citizens was admirably expressed in a letter on p.2 of *The Scotsman* on 20th. The reader should bear in mind that photography was in relative infancy still, and most newspapers in 1860 contained no photographs. Writers of the day, in describing events, therefore used prose often found more picturesque than that written today . . .

E.g., referring to "The Police and the snow", our anonymous 1860 author writes:

. . . "These magnates actually threaten the householder with heavy penalties if they do not turn out in the early morning and once or twice a day as well to clear away the snow from the pavement in front of their own house. But, having looked out in front of my house and up and down the street, I do not see the smallest particle of snow yet removed from the centre of the street by any police cleaning officials, while on the pavement, I see a set of regular roughs, terrifying the servant maids into paying them 18 pence each for five minutes spade-work before each house, and claiming this exhorbitant wage under authority of the police advertisement in your columns".

I am. etc., "A Householder paying the Police Cleaning Rate".

Thus, the law was quite vividly illustrated as being, at very least, impractical given such deep snow. One wonders if readers in other countries are still legally-obliged to clear snow from in front of their homes and business premises? This author believes it is a continuing requirement in some West German urban environments, for example.

The extent of fairly-deep snow cover associated with the 'Polar Low' is described in private diaries and by further reports (e.g. in *The Times* of 20th December).

"On Wednesday morning the northern counties from Coast to Coast appeared in a covering of snow. At Liverpool, Manchester and at Bradford there was a uniform depth of 5 or 6 inches and locomotion was suddenly and unexpectedly impeded. From Liverpool to Manchester there was little variation in the depth of the snow which had fallen evenly and without drifting. Between Manchester and Sheffield the depth of snow gradually diminished and in some places south of Sheffield, the ground was barely covered. Towards the Midlands, there had been a heavier fall".

With only a light "one-inch total cover" reported from Bristol, there has to be some suspicion that major enhancement of precipitation occurred through the Cheshire Gap and on, south-eastwards, resulting from more-vigorous convection initiated over the Irish Sea, if not the North Channel (see Browning et al, 1985). On the 19th, Thomas Plant recorded snow continuing "for most of the day, with a southerly wind veering northerly by noon", resulting in a 10-inch (25cm) undrifted accumulation at Moseley Road, Birmingham; then observers on the Kennet and Avon Canal at Reading and Pewsey noted "rainguages frozen and covered by deep snow from 19th to 29th inclusive". At Southampton, the Royal Engineers timed the snow as commencing at 1245 p.m. on the 19th, continuing through the afternoon and night to measure a 1.00 inch water equivalent of snowfall the next morning. By mid-day on the 19th, Wales and Northern Ireland had been blanketed, then continuing southwards; snow in the evening was reported to have given a 2½ -inch (6cm) fall in normally-mild Torquay in Devon, and a 2-inch (5cm) covering had fallen at Uckfield, Sussex, by 11 pm, with 1 inch at Cobham. This snow barely affected other south-eastern counties, with diaries from Lincolnshire and East Anglia having no record of any. In London, Thomas Cator, a clergy-man's son living centrally at Bryanston Square, W1, mentioned a "brief but fast snowfall from 8 to 8.45 p.m. which covered the ground" in the capital. His interesting diary contains many *'Times'* press cuttings of the outstanding cold weather which was to follow, and is one of many diaries archived at Eastern Road, Bracknell Meteorological Office.

A clear picture emerges of an active, early-wintertime 'Polar low' blanketing most of the British Isles with snow by morning on 20 December 1860, with only some areas in the south-east, and other localities sheltered from the north-west by high ground, escaping.

COLD AIRFLOW AND SNOW SHOWERS OF 21-22 DECEMBER 1860

Following the passage of this 'Polar low', minor troughs crossed the British Isles in a persistently-cold, north to north-easterly airstream, bringing widespread snow showers, especially after noon on the 21st and early on the 22nd in southern and eastern England (Fig.2b). At 09 hrs on the 22nd, water equivalents of snowfall over the past 24-hours in Camden Square, London, measured 0.69in. Absence of reports of snow depth indicate that measurements were difficult and not attempted by even the most ardent diarist in prevailing conditions variously described as 'Stormy' or 'Very Windy', since drifting would have occurred in the blustery showers. Force 8 gales were reported down the east coast from Berwick to Dover on the 21st, but winds had moderated somewhat on the 22nd. Telegraphic reports from the 23rd are missing, but the weather that day appears to have been in a transitory phase, with clear conditions inland, and snow showers largely confined to the east coast. (Scarborough remarked it was a "snowy day").

Over this period of 21-23 December, at least a patchy new snow cover would have been added, more especially in south-eastern areas of Britain hitherto unaffected, and with no significant melting of the general blanket elsewhere; approaching Christmas 1860 most of the British Isles appears to have been under a drifting cover of relatively fresh, dry snow. Roach and Brownscombe, 1984, link a "fresh snow-cover of moderate depth" with screen minimum temperatures below

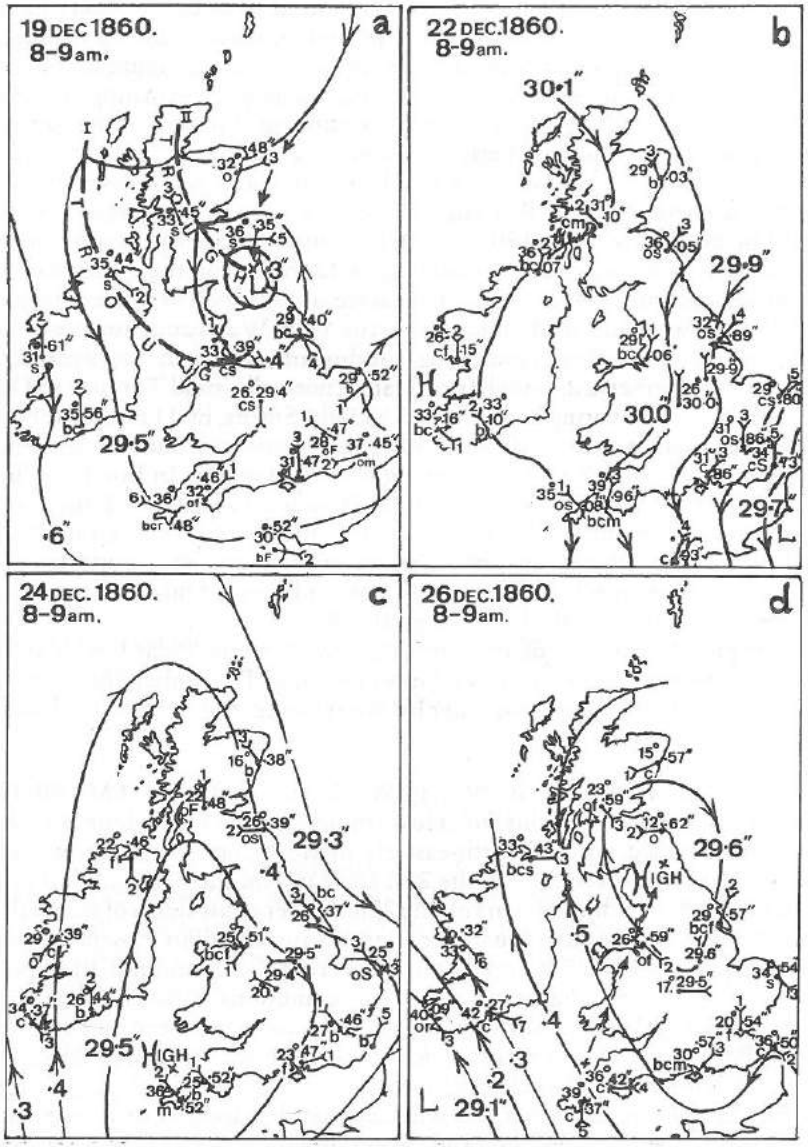

Fig.2: Four surface charts over the period 19-26 December 1860 based on information supplied by the Meteorological Office. All wind directions are plotted conventionally. Coastal telegraphic stations estimated Beaufort Force, which is represented numerically (0-7) at arrow-tails, and they reported m.s.l. pressures in inches of mercury, with tenths and hundredths plotted here. Inland observations are from Birmingham (T. Plant) and Beeston Observatory (E. J. Lowe), with m.s.l. pressures corrected to the nearest tenth. All temperatures are dry bulb and in degrees F., with Beaufort letters of current usage describing present weather (except 'p for shower' and other refinements such as 'double letters for continuous' are omitted since they had not, as yet, been defined). the weather reported was observed between 0800 and 0930 hrs.

–20°C which were recorded somewhere in the UK over 12-13 December 1981 and 7-14 January 1982. Approximate definition of 'fresh' appears to be 'between 2 and 5 days old' and the meaning of 'moderate depth' is '10cm or more', following the authors' diagrams. Buchan's "Report on the great cold of Christmas week 1860" stated . . . "it deserves notice, that those places where the greatest amount of snow fell, afterwards experienced the greatest cold".

THE LOW TEMPERATURES: THEIR MEASUREMENT AND EFFECTS

Following the snowfalls, widespread slight to moderate frosts occurred throughout Britain, but it was not until the night of 23-24 December that there was a generally-severe frost, with a minimum of –20°C recorded in Scotland (–4.7°F at Thirstane). The Serpentine froze over in Hyde Park, London, and at 3.30 pm on Christmas Eve, despite the efforts of those who tried to save him, a man drowned having fallen through the ice, observed by "one who values human life" writing in *The Times* of 26th December (newspapers were printed in limited editions on Christmas Day).

Remarks should be made on the thermometer exposures of the day, which were by 1860 standardised at 4ft above the ground in a sheltered or screened location, with a few exceptions. At the Ordnance Survey in Edinburgh, a fore-runner to the Stevenson screen was used, although these did not come into widespread use for another few years, and generally, either thermometer 'stands' were utilised or else instruments were suspended on a north-facing wall. Minimum thermometers of the self-registering type had not been reliable until the mid 1820's when the familiar blued-steel dumbell-index was introduced (Middleton, 1966, p.152). Within 10 years of this development, it appears that the necessity to suspend more than one instrument at a set height led to the introduction of various stands. Because initial design of the revolving 'Glaisher' or 'Greenwich' stand appears attributable to Sir George Airy, according to Ellis (see Middleton, 1966, pp214-5), and thermometers are drawn exposed at 4ft in the design plan, it can be argued that the 4ft standardisation might well have originated in the domineering, orderly mind of the Astronomer Royal, who would have appreciated the effects of radiation on temperature more than most, and had the influence to have his own rule accepted as the standard.

Conducting a study of 40 years' recorded minimum temperatures at Camden Square, London, Margary (1924) found the Glaisher stand readings to be generally 0.8 to 1.3 deg.F lower than comparable temperatures recorded nearby in an enclosed Stevenson screen. Ellis (1891) had made an earlier but less-conclusive study, comparing readings at Greenwich. Since fully-calibrated minimum thermometers were, in 1860, being manufactured by Negretti and Zambra and other reputable makers, we might estimate the readings mapped in Fig.3 are probably comparable to within 1 or 2 deg.C of values which we might measure in a modern, enlarged Stevenson screen today, with thermometer bulbs exposed at 1.25m above ground level. Figure 3 indicates minimum temperatures recorded overnight 24-25 December, when occurred the most widespread very severe frost. The only non-standard exposure heights of thermometers above ground level were noted as 5ft at Chatteris and Dymock and 6ft at Wigan; other observations were at the recommended four-foot standard. Two stations in Scotland and two in

England dipped to -14° or -15°F (about -26°C), with unsubstantiated reports of -20°F (-29°C recorded at Carstairs (near Lanark; see Buchan, 1861, p10) and in the southwest suburbs of Glasgow, where some amputations in extreme cases of frostbite were necessary (personal communication, A. F. Wills). Were these reports authenticated, the British record for minimum temperature would be in danger! Also in Glasgow, the rivers Clyde and Kelvin were already frozen over on Christmas morning, and some trees had been split open by the severity of the frost.

Writing from Beeston Observatory, Nottingham, at 12.30 pm on Christmas Day, E. J. Lowe remarked:

> "From 7pm (yesterday) 'till 11 am (today) the temperature never rose as high as zero on Fahrenheit's thermometer. At present time (it) is 7 deg. above zero at four feet . . . the sky is cloudless with a fog in the distance. The Trent is full of ice and in a few hours will be quite frozen over. I have just seen a horse pass by with icicles at his nose three inches in length . . ."
>
> (From letters to *The Times*, 27 December 1860

Further correspondence in *The Times* indicates that the Serpentine in London was being used more successfully for skating by the afternoon of Christmas Day with "hundreds of revellers" including many soldiers from the nearby barracks, some of whom sustained sprains and other injuries caused by bumps and crashes on the unfamiliar ice. There is every reason to suppose that, in another part of London, this abnormally cold weather was causing the River Thames to freeze over, so providing the youthful Whistler with inspiration for a unique painting on an unusual theme for Christmas Day.

"The Thames in Ice" (Figure 1) was first called "Twenty-fifth of December, 1860, on the Thames" when exhibited at the Royal Academy in London in 1862. It was begun *in situ* and completed in three days (by the 27th December 1860) in an inn at Cherry Gardens, Dagenham (see Pennell, 1908, p89). The river is quite wide here, and presence of large ships confirms the location as being well below Tower Bridge. Four smoking chimneys in the distance indicate a north-easterly drift of wind, and they are probably at works on the Erith marshes. There is much ice depicted on the river, and only small areas where boatmen are active in the foreground remain clear.

BRIEF DISCUSSION AND CONCLUSIONS

Forbes and Lottes (1985) have attempted a classification of mesoscale vortices in polar airstreams, 133 of which were observed between 1st December 1981 and 5th January 1982 in satellite images of the N.E. North Atlantic. From their categories of cloud patterns and Figure 2a, it seems likely that the 'Polar Low' of 19 December 1860 was either, and most probably, of the "Comma: Deep convective spiral (type 1c)" with two bands of cloud (labelled 'Troughs I and II' in Fig.2a – see also Fig.4), or possibly, a single "Crescent or Horseshoe-shaped (type 3) vortex" (see also Rasmussen, 1987, pp214-5).

After a mild first two weeks in December, snow cover was persistent over much of Britain following passage of this 'Polar Low', resulting in extremely low temperatures when a relatively-small anticyclone with calm conditions and subsiding air moved slowly-northeastwards between 23rd and 27th December

1860 (Figs.2c and d). A correspondent to *The Times*, writing from Plymouth on Christmas Day remarked "It is very unusual for snow to remain long on the ground in this vicinity, but for nearly a week past the town and neighbouring country have been covered".

Undoubtedly the cold period was longer-lasting over Scotland, as Buchan had suggested, with deeper snow a contributing factor to night radiation. At Thirlestane, successive minima from 22/23-27/28 December were -4.7, -6.7, -8.7, -0.7, +4.3 and +2.3 deg.F. Correspondence to *The Scotsman* on 28th December remarked on the depth and extent of ice which resulted, a writer from Bathgate remarking "Curling goes on from morn till dusk", and in Edinburgh, "The ice on the lochs around Arthur's Seat is, on the average, between five and six inches thick, and is covered day after day with a multitude of skaters, curlers and promenaders". Another correspondent remarked . . . "yesterday the Firth of Tay was filled from shore to shore, from the river to the sea, with huge blocks of ice piled on top of one another to an average height of seven feet". Pearson (1978) makes extensive quotes from other Scottish papers of the day, which suggest the frost had not been so severe for 46 years (*Caledonian Mercury*), and the depth of snow was unprecedented since 1823 according to the *North British Agriculturalist* (Pearson, pp398-9). A check of Manley (1974) confirms the Januaries of 1814 and 1823 to have been extremely cold in Central England, also.

There were corroboratory cases of frostbite reported on Christmas Day, including a labourer in Suffolk who awoke with a frostbitten hand. Much general inconvenience was experienced due to freezing in water pipes. However, for James MacNeill Whistler, who had been stung by some harsh criticism that he was an "idle apprentice" (Pennel, 1908, p89 remarks on this), the bitter weather gave an excellent opportunity to prove himself to be a genuinely keen and energetic observer of Nature, so when the Thames was first noticed to be frozen over, the painting begun on Christmas Day may be taken as solid evidence in Whistler's favour.

From Figure 3, it may be seen that there were four readings below Greenwich's 8°F on Christmas morning in the capital. Of these, Lewisham and Chiswick may both have been recorded in much more rural surroundings than today. However, the 6.7 degrees F. measured outside the Meteorological Society's rooms in Camden Square was overlooked by Glaisher (1861) for some unaccountable reason, despite being registered on a tested thermometer hung in an approved Glaisher stand . . . identical exposure-type to Greenwich, where Glaisher was then Superintendant of the Magnetical and Meteorological Department (see Hunt, 1978). If one applies the '+1.3 deg.F' correction suggested by Margary (1924) to both Camden Square and Greenwich observations, the record December minimum for *urban* London remains 8°F (-13.4°C) but is held by Camden Square not Greenwich.

Roach and Brownscombe's (1984) finding that "extreme temperatures were recorded under clear skies two to five days after extensive snowfalls" (p363) in 1981-2 is corroborated by this study of December 1860, because even in N.E. Scotland where very cold weather persisted until 30/31 December, further snowfalls had occurred until Christmas Eve.

Fig.3: Pecked isotherms indicate approximate areas where minimum temperatures overnight 24-25 December 1860 fell below 0°F (−18°C) and −10°F (−23°C). Those few wind directions and m.s.l. pressures that were reported early on Christmas Day suggest an anticyclone of central pressure approximately 29.6 inches was centred over Liverpool Bay at about 09 hrs. (Scottish observations of pressure were made at 0930 hrs). There was a suggestion of another centre moving slowly north-eastwards over East Anglia at this time.

Acknowledgements: My gratitude to Laveta Emory at The Freer Gallery of Art for copyright permission to reproduce Fig.1. At the National Art Library, Victoria and Albert Museum, Kensington, special thanks to Mrs Gillian Varley; also to Benedict Read, Deputy Witt Librarian at the Courtauld Institute of Art, University of London, for their kind co-operation in sending information on Whistler and his friends, the Pennels.

At Bracknell Meteorological Office, Eastern Road Archives, thanks to Mick Wood for helping me access private diaries of 1860. At the National Meteorological Library, my gratitude to Ron Mason for posting 'Middleton', and also to Maurice and David Greene for their assistance. At Edinburgh Meteorological Office, thanks to Miss Marjorie Roy for sending 'Buchan', and specially to Andrew Wills for his delving into records and supplying additional information on Glasgow, Edinburgh and Stirling observations. At Birmingham University, my appreciation to Dr. Brian Giles in the Department of Geography for information on Thos. Plant's station data, and in London thanks to libraries at the Science Museum, the Museum of London (EC2), Marylebone Central Library, and the British Newspaper Library. Finally, my gratitude goes to Messrs. Ayres and Durham for their thoughts on thermometer exposures.

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A 360-DEGREE ANEMOMETER SWING AT WOKINGHAM ON 16 JUNE 1988 ASSOCIATED WITH A PROBABLE VORTEX IN THE NORTH-EAST AIRFLOW DOWNWIND OF A SMALL HILL

By BERNARD J. BURTON
27, Cantley Crescent, Wokingham, Berkshire.

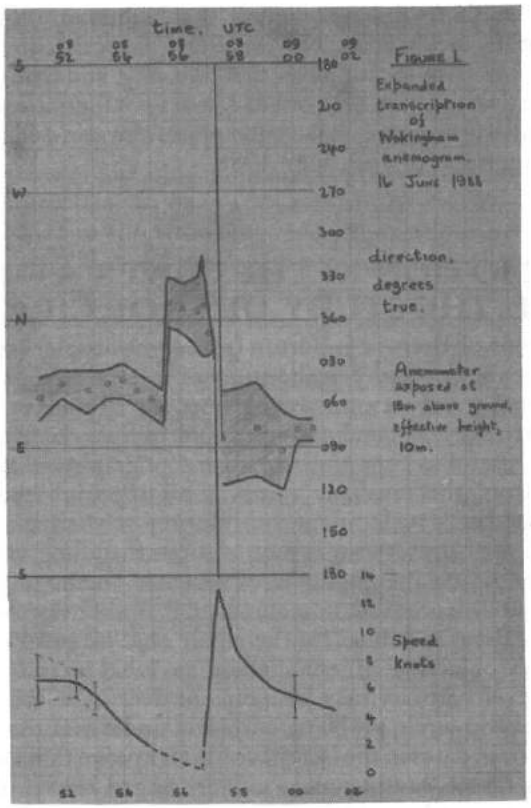
After reading the interesting article in *Journal of Meteorology, 13,* 132, pages 305-310, concerning vortices observed near Avebury on June 16th 1988, I decided to compare the anemogram for Wokingham (Berkshire) with the one shown for Lyneham (Wiltshire) in the article. To my surprise I found that an interesting and unusual event had been recorded on the Wokingham anemogram almost two hours later at 0857 UTC, where the direction rotated through more than 360 degrees coincident with a gust of 13 knots, with a background mean of around 5 knots. From subsequent analysis of the event, it is concluded that a moving vortex whose axis passed close to the anemometer was probably responsible. Later in the morning at 1040 UTC another event occurred which caused the direction vane to swing through 360 degrees, but this time it was associated with a speed minimum of less than 2 knots.

Figure 1 is an expanded transcription of the relevant 10 minutes, the direction plotted as an envelope within which the vane was oscillating, and the speed plotted as an approximate mean of about 15 seconds, with typical gust/lull range shown in a couple of places. The speed trace for minutes 55.0 to 56.8 has been shown dotted as this portion is estimated because the cup generator had stopped rotating for this period, indicating no gust greater than 4 knots. The direction vane was still quite active though, so the speed did not fall to zero.

Although some 70 km from the Avebury area referred to in the article, Wokingham was under a similar wind regime, to judge from the Lyneham trace, although with a very slightly higher speed. The hourly mean wind at Wokingham for the period 0400 to 1100 UTC was as follows:

Hour	Direction	Speed	Gust
0400	030	01	02
0500	040	03	07
0600	060	05	10
0700	060	05	10
0800	060	05	13
0900	040	05	09
1000	030	06	11

Looking at the expanded plot, Figure 1, some idea of the overall size of the probable vortex can be obtained if some assumptions are made about its velocity. If one assumes that it was moving at the average speed of the 10-metre wind, about 2.5m sec^{-1}, then from the speed trace in Fig.1, a diameter of about 1 km is suggested. However, if the vortex was much deeper, perhaps the roots of a circulation near the top of the developing boundary layer, its velocity would have been a good deal higher, perhaps nearer 5m sec^{-1}, with the resultant diameter near 2 km. Perhaps a better way to estimate the size of the vortex would be from the direction trace, in which case a much smaller circulation is suggested, between 300



and 600 metres. From the region of the trace between minutes 57.2 and 57.5 which contains the peak speed of 13 knots and a direction change of 420 degrees, a diameter of between 45 and 90 metres is suggested for the central core of the vortex.

Of course, there is no evidence to suggest that this probable vortex at Wokingham was generated in a similar way to that proposed by Dr. Meaden for the Yatesbury example, especially as the topography in the vicinity of the Wokingham anemometer is rather gently undulating, varying between about 40 and 80 metres AMSL. Nevertheless, there is a hill of roughly circular aspect located just over a kilometre upwind of the Wokingham anemometer, though the difference in height between the ground in the vicinity of the anemometer and that at the crest of the hill is a mere 25 metres.

In conclusion, it is interesting but perhaps only coincidental that an apparent vortex event was registered by the Wokingham anemometer on the same morning as the observation of vortices above a wheatfield near Avebury, 70 km to the west. Although the Wokingham event was almost two hours later than the Yatesbury one, the obvious deepening of the boundary layer by this time and the suggested overall diameter for the Wokingham vortex, possibly being as large as

two kilometres, would lead one to expect that a thermal plume was the most probable generating mechanism. Nevertheless, one can conclude that similar conditions existed at both locations on that morning, and that the requisite flow conditions coupled with a suitable boundary layer configuration conducive to the formation of small vortices may have been present over a wide area of Southern England on the morning of 16th June 1988.

An Experiment

VORTEX MOTION IN THE LOWER ATMOSPHERE AND THE STUDY OF CROP CIRCLES

The observations of Bernard J. Burton (preceding article) are illuminating for the application of anemography to the study of local vortex development in the lower atmosphere. Such observations could be of significance in the study of eddy-vortex formation in the lee of undulating ground, hills and escarpments, and might prove especially useful where the irregular topography is a seemingly weak feature remote from the resultant vortex. This approach should also provide information about the development and motion of thermals and whirlwinds, besides the passage of stray twisters such as aircraft trailing vortices.

Would readers having anemographs, or access to anemographs, care to check their records for 360-degree anemometer swings in the way that Mr Burton has done? Analyses of dates and times for the whole of 1987 and 1988 would be very helpful, with the objective of establishing to what extent and under what conditions low-level vorticity may be incipient over wide areas of the country.

As regards the crop-circle problem, currently under vigorous investigation by the author, for certain dates in the last six years it is known that crop-circle vortices of specific types (those causing plain circles, ringed circles, doublets, triplets, quintuplets, etc) appeared in widely-separated areas possibly sometimes at much the same hour. This suggests a large-scale vortex impregnation of the atmosphere and quite general conditions for the criticality that leads to vortex-breakdown and ultimately to ground-level damage.

Additional data would be generated from examining the evidence of closely neighbouring anemometers such as the sense of rotation and the rate of growth or direction of movement of particular vortices.

For the busy reader who can help in this inquiry a chart-study for the following dates, night and day, would be useful to start with:

1985 – January 27; May 7; June 16 and 29; July 6, 20 and 31.
1986 – April 5; July 5, 13, 25, and 31; August 14 and 24.
1987 – May 8; June 8-9 and 14; July 4, 10, 24, and 28-29; August 1-8; 14-15, 20-22, 28-29.
1988 – June 4, 10-11, 16-20, 24-25, 30; July 1-4, 14-16, 26; August 4; September 11.

For investigators with more time, please also include dates starting just before the ones indicated. A longer list can be provided upon request.

G. T. MEADEN

EXTREME WEATHER EVENTS IN SWITZERLAND 1525 – 1863

By H. J. SCHUG
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In a time of apparent increasing numbers of extreme weather-events around the globe, it is very interesting to have a look at similar events in former times.

For the period 1525 to 1863 (the time before the setting up of the Swiss national observation network) Dr. Christian Pfister collected all available historical information, concerning weather. The material came from chronicles, personal diaries with sporadic weather-information and first observation logs (containing even instrumental data). Altogether, 118 handwritten and 150 printed sources found in archives and libraries were used from the period 1525 – 1863. About 33,000 "records" with a temporal resolution of one decade could be created for this space of time. They contain among other things 3000 phenomenological observations and detailed descriptions of the snow-cover at different altitudes.

Naturally the amount of information increases with time. From 1550 on, for 99% of the months there is at least one report. The most reports are from the summer months. The greatest omissions are for the months October and November. The result of this work, containing the types of data used, data criticism, reconstructed temperature-and rainfall-pattern for this time, and social effects are published in the two volumes of "Das Klima der Schweiz 1525 – 1860 und seine Bedeutung in der Geschichte von Bevölkerung und Landwirtschaft" (Pfister, 1984).

The complete data-set, called CLIMHIST can be obtained from METEOTEST, Hallerstrasse 50, CH-3012 Berne.

In the following a revised and shortened translation of the part "Remarkable seasonal weather-anomalies" from Vol.1 "Klimageschichte der Schweiz 1525 – 1860" is presented.

Until the late 18th century weather anomalies were always regarded as a penalty for transgressions of humans against divine commandments. In modern times this attitude has changed to "penalty for transgressions against nature" (caption: air pollution, greenhouse-effect). The "historical memory" of the population has always been very short-lived. With the following discussion of remarkable anomalies of former centuries it should be demonstrated that the natural variability of our climate is much greater than meteorological statistics of the last hundred years can reveal. In so far as climate conditions of the last 10,000 years lie within the scope of the last centuries, one can assume that anomalies since 1525 approximate to the extreme values since the last glacial period.

SIBERIAN COLD-SPELLS

The five winters 1573, 1684, 1685 and 1709 could be considered as the most severe of the pre-instrumental period. In detail the documents for the winters are:

1572/73

November 1572 was roughly 5-8 degrees colder than average, and together with the Novembers of 1613 and 1676 one of the most wrathful of the last

centuries. Till the end of the year there fell a lot of snow. In Grindelwald "men and cattle" were crushed to death in the houses by the snow masses". A lot of rivers (e.g. Rhone in Valais and Rhine near Bale) and lakes began to freeze up. For a solid icecover across rivers there has to be temperatures down to –30 deg C. Several invasions of cold air occurred in that winter, always connected with a strong bise (cold, northeasterly wind on the Swiss plateau). On the 2nd February 1573 Lake Constance became covered with ice for 60 days. Also Lake Neuchatel and half Lake Geneva got frozen. Remarkable are early beginning and the extraordinary length of the cold-spell: from the beginning of November till the end of March. Lake Constance remained frozen twice as long as in the year 1830.

1683/84

After a mild and snowless start to winter in December, on 11th January 1684 started the cold-spell. A chronicler complained that, despite heating, the ink became frozen in his pen. Wine froze, trees cracked with a loud bang. Near Zurich a hungry wolf was shot. At the beginning of February several lakes with the exception of Lake Neuchatel froze up again.

1684/85

The cold spell started in November. Zurich reported 20 days with snow-cover, indicating a temperature deviation of about –4 deg. After a short mild foehn-period in mid-January, the bitter coldness returned with strong bise in February and lasted till 18th March. The great lakes got frozen, but the ice was not apparently as thick as in the former severe winters.

1694/95

Moderate chillness started in Zurich around 20th November. Until mid December it was dry and cold with persistent fog over the Swiss plateau. Then the cold spell intensified and reached its climax at the end of January. All lakes, including Lake Neuchatel, froze up and carried even heavy-loaded sledges.

1708/09

The remarkable feature of this "Great Winter" is its wide extension over many parts of Europe (Rowe 1988) and the very low temperatures measured for the first time with thermometers. From the available reports one can conclude that the start and end of this cold spell occurred nearly at the same time throughout Europe. At the same time, when Berlin reported its lowest temperatures (–30 deg C), in Switzerland the coldness reached its first climax. Half of the River Rhine near Bale got frozen. Fruits and wine froze in the cellars. In many places cattle had to be taken into heated rooms to prevent them from freezing. In Geneva children were retained in bed day and night. Birds fell unconscious from the trees. Trees cracked (this occurs at temperatures below –25 deg C). Due to the strong bise the lakes froze up only at the edges.

SPRINGLIKE WINTERS

1529/30

There are reports from St. Gallen (eastern part of Switzerland, 670m) that there was no snow during the whole winter. In February several flowers bloomed and

frogs croaked. At the end of March cherry-trees were in full blossom (about 10 days before the earliest date recorded in the 20th century). These reports indicate that February and March 1530 had the same mean temperature as an average April! The winter 1529/30 was probably the warmest of the last 450 years.

1606/07

This was also a winter with scarcely any snow-cover and early flower blossom (e.g. violets in February in Lucerne). The three winter months were as warm as a typical March. The winter 1915/16 of our century might come up to that winter.

Remarkable, but shorter "warm-spells" occurred also in the winters of 1602, 1603, 1609 and 1610.

WINTRY SPRINGS

The following list is arranged in the sequence of the three spring months.

1785

In Bale mean temperature of March was 8 deg C below the average 1901-60, resembling more a January. This cold-spell also affected many parts of Europe, and the following April was also very cold (Bale:– 3 deg). Until mid-April the Swiss plateau (altitude: 400-500 m) was covered with snow. On 3rd April Berne reported 120cm of snow!

1614

Snow-cover which started in November 1613 lasted 20 weeks until April.

1601

First 18 days of April were very cold, so that the winter snow-cover first disappeared locally (e.g. Lucerne) at the end of April.

1699

A wet and cool April increased the snow-cover in many parts of Switzerland during the month! In the lowlands snow-cover first disappeared in mid-May.

1700

According to reports of frequent snowfall and permanent snow-cover this April was about 6 degrees colder than normal.

1578

On 25th and 26th April Arctic air initiated an extremely cold period, lasting till the end of May. "Vierwaldtstaettersee" got ice-covered, which normally only occurs in the winter months. On the last 6 days of the month snowcover lay down to 500 metres, approximating a temperature-deviation of –7 deg C, compared to 1901-60 average.

1698

Cold and wet May. Zurich (500m) reported 23 days with rain, then 5 days with snow. Similar unpleasant May weather occurred also in the year 1740.

10-MONTH MEDITERRANEAN CLIMATE – THE YEAR 1540

This year was probably one of the most exceptional in our millenium, because Central Europe was situated for months in a subtropical belt. Consistent reports say that there was only sporadic rain from February until the end of the year. Zurich reported only six rain-days from mid-March till the end of September. At Christmas boys paddled in the River Rhine near Schaffhausen. In this extreme year, rainfall amounts were only a third of the normal. Because of the high temperatures, vegetation was four weeks in advance at the beginning of July. Similar hot "summer-starts" have indeed been observed in 1636, 1638, 1660 and 1822 and 1893, but in contrast to these years the heat-wave in 1540 lasted for the whole summer. Some effects of this remarkable summer: widespread forest-fires, dry rivers, cessation of mills and strong glacier melt. The drought of 1540 placed that of the year 1947 in the shade. 1540 can probably be titled the sunniest year of the last 500 years. The wine – although the vintage was meagre – was very racy!

HEATWAVE OF 1616

For the last 500 years this summer was the hottest. Phenological data indicate that June temperatures were close to the theoretical thresholds which can be expected after several weeks with strong insolation. The dry period lasted in the northern part of Switzerland about 50 days – twice the number of the famous dry summer of 1976. Vintage started around 10th September and was probably the most abundant of the 16th and 17th century.

YEARS WITHOUT SUMMER – 1628 AND 1816

In contrast to the preceding hot summers 1540 and 1616 these two summers are typical extrema within the so-called "Little Ice Age". In 1816 July and August (with 14.8 deg C) were in Bale comparable to a very cold modern June. In addition there fell a lot of rain, frequently to 1000 metres as snow. The start of the rye-harvest and vintage was about a month later than usual. In Grison potatoes were at the end of September as green as in July! Similar reports come from the summer of 1628!

CAPRICIOUSNESS OF THE AUTUMN-WEATHER

1587

In September snow-fall occurred even on the Swiss plateau (e.g. Berne). Similar cold Septembers occurred in 1755 and later on in 1885 and 1912.

1551

The first decade of October already brought snow to the Bale area! Trees, still in leaf, collapsed under the weight of the wet snow. For the rest of the month the Swiss plateau remained snow-covered. This would correspond to a temperature deficit of about 8 degrees.

1740

The wintry cold-spell started on 8th October, lasting till the end of the month. Similar wintry Octobers were reported from 1594, 1688 and 1694.

1599

A very warm autumn, causing a second blossoming of fruit-trees and the development of edible fruit. October 1599 was probably 4 degrees warmer than average.

Reports of long-lasting warmth and sunshine occurred in this space of time in other seasons also providing a further document for extreme long-lasting blocking situations around the turn of 16th to the 17th century.

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THE SMETHWICK BALL LIGHTNING REPORT

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Abstract: A report of a fireball in a kitchen during a thunderstorm was attributed to ball lightning. It damaged clothing and apparently heated a wedding ring. The investigator rejected other explanations even though the ball's characteristics are consistent with those of burning methane at very low density. It is concluded that the ball was a spherical flame of methane ignited accidentally by the witness. It had nothing to do with the thunderstorm and was not ball lightning.

THE INCIDENT

During a violent thunderstorm over Smethwick (English West Midlands) at about 1945 BST on 8 August 1975 a woman encountered a fireball in her ground floor kitchen. She had just filled a kettle with water and turned toward the gas cooker (or had already put the kettle on the cooker) when she saw a ball appear above the cooker. It was a sphere about 100mm in diameter with a bright blue to purple core surrounded by a flame-coloured halo. She felt burning heat and heard a sound 'like a rattle'.

As the ball moved toward her at about waist height she screamed and brushed it away with her left hand. It then seemed to explode or disappear with a very loud noise. There was then a singeing smell. Afterwards it was found that a hole had been melted in her dress and tights and her left hand was red and swollen. Because her wedding ring seemed to be burning into her finger she had to force it off under running cold water. The ball had appeared for only about 1 second.

DISCUSSION

The circumstances of this incident have been described several times (e.g. by Stenhoff, 1986) although not in as much detail as I would like. From the start Mr Stenhoff described it as an incidence of ball lightning although lately he has declared that he does not know the cause of the event (Stenhoff 1988).

In 1986 Stenhoff concluded that the report resisted attempts to explain it in terms of phenomena other than ball lightning (a term he did not define) even though he showed that the energy content of the ball was roughly equal to that of a

similar volume of burning methane. He appears to have rejected the burning methane hypothesis on the grounds that it could not assume near-perfect spherical symmetry for a period of 1 second. However Barry (1980) exhibited a photograph of a spherical ball which he produced in a laboratory. The ball was produced by igniting propane at a concentration of 1.4 –1.8% in air at surface atmospheric pressure. This concentration is less than that necessary for ordinary combustion of propane in air (2.8%). The ball produced by Barry was yellow-green, brightly luminous, had a diameter of several centimetres, exhibited rapid random motion and decayed silently 1 to 2 seconds after removal of the source of ignition (an electrical spark). Barry's was not the first experiment to show this phenomenon. Other experiments have shown that the colour depends on the gas used (I have not found what colour is expected of methane) and that at high concentrations a slight rustling noise is audible.

The behaviour and appearance of the Smethwick ball are so similar to those of balls produced in low-density hydrocarbon gases in air that it must be considered that the ball was a spherical flame of methane at a density below the normal combustion limit (5.4%). This hypothesis is strengthened by the fact that the ball appeared above a cooker fuelled by methane (natural gas) at, or about, the time when the gas was being lit to boil water. There is some doubt about the exact sequence of events and Stenhoff does not state when the gas was ignited or what device was used to ignite it. It seems probable that the ball appeared at the time of gas ignition, or very shortly afterwards. If the gas tap was turned on a little too long before ignition, enough methane may have been released to produce a concentration in the critical range in the space above the cooker. The damage to the witness' dress and the reported heating of her wedding ring are explicable by this hypothesis. That she felt 'burning heat . . . all over' is no reliable guide to the ball's radiation intensity; a subjective process may have been responsible, at least in part.

There is no certain connection between the ball and the contemporary thunderstorm. The witness cannot recall whether she saw the ball before or after a clap of thunder. No evidence has been produced that lightning struck the ground or buildings nearby. The 'explosion' with which the witness thought the ball vanished may have been a coincident thunderclap.

Stenhoff claims that his estimate of the energy content of a methane/air ball of 10cm diameter at a temperature of 6200K (700 joules) is consistent with the estimates of thermal energy of the ball. However one estimate he quotes (by Wooding) is more than 2 kilojoules! Barry's estimate of the total energy in the ball is only 440J, which is more consistent with Stenhoff's estimate. At the low concentration of Barry's experiment the temperature would be lower than that given by Wien's law, so reducing the energy content near to that of Barry's estimate. Consequently it can be claimed that the energy content of the Smethwick ball was roughly equal to that of a similar volume of burning methane, but at a concentration below the normal combustion limit.

CONCLUSION

During a thunderstorm the witness turned on a gas ring of her cooker and was somewhat slow to ignite the gas. Either at the moment or just afterwards the low concentration of unburned methane above the cooker became ignited, either from the burning ring or from the source of ignition used by the witness. It was coincidence that the incident occurred during a thunderstorm but this coincidence led to the ball being described as 'ball lightning'. If ball lightning is defined as a phenomenon involving continuous electrical discharge, then the Smethwick ball was not ball lightning.

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WORLD WEATHER DISASTERS: MAY 1988

1: Tornado hit Chaoyang county, Guangdong province, south China, leaving five dead, 40 injured and damaging nearly 300 homes, the tornado was about 4.8km long. *Lloyds List.*

1: Thunderstorms in areas of Great Britain, three deaths reported from lightning strikes, one died on Helvellyn, in the Lake District, with another two reported injured; another person died on Great Rigg, near Ambleside, also in the Lake District, with a further three others injured; the third death, another walker, reported from Caradoc Hill, near Church Stretton, Salop; in the Ambleside area of the Lake District, several houses hit by lightning. On the 4th lightning hit a power station at Willoughby-on-the-Wolds, Nottinghamshire, setting it ablaze and blacking out thousands of homes in south Nottinghamshire. *Daily Telegraph. Birmingham Evening Mail.*

2(reported): Water level in Lake Nasser, behind the Aswan Dam in Egypt, has fallen from 166 metres to 150 metres as drought in upper reaches of Nile river continues. *International Herald Tribune.*

3(reported): Giant mudslide swept through a village in Afghanistan devastating hundreds of homes and leaving 35 dead. *L.L.*

4: Avalanche swept down mount Sissone, Switzerland, leaving five dead. *I.H.T.*

4: Flash flood along Citanduy river in Cilicap regency of central Java, Indonesia, left five children dead. *Jakarta Post.*

7(reported): Hailstorms in past week in Jiangsu, province, central China, left 17 dead and 120 injured, the hailstones, some as big as eggs, accompanied by high winds destroyed or damaged thousands of buildings and thousands of acres of summer grain crops, hail reported to be up to 58mm deep. Storms in Anhui province destroyed or damaged 300,000 houses, leaving three dead and 105 injured; in Henan province hailstones left one child dead and 85 other children injured as they were on way home from school. Meanwhile im Hubei province, also in central China, the worst drought in 100 years has destroyed more than 32 million acres of farmland and dried up much of the province's water supply, temperatures in the area have risen to an unusual 38°C. *D.T., L.L., I.H.T.*

8: Torrential rains in south-east England flooded homes and roads; homes in Pinner, Northwood, Hatch End and Harrow were flooded up to a depth of one metre; at one point 50% of Harrow reported to be under water, over 25mm of

rain fell at R.A.F. Northolt, at nearby R.A.F. Uxbridge the river Pinn burst its banks, flooding the base, floods persisted till the 9th in areas; water three metres deep blocked the Medway underpass on the A40 at Perivale; on the 10th a railway bridge weakened by floods collapsed near Wraysbury, Buckinghamshire, as an empty passenger train passed over it, the wheels of the last carriage derailed, no casualties reported. *D.T., L.L., Birmingham Evening Mail.*

9: Series of violent storms in areas of the mid-west, north-east and southern United States of America; a tornado hit city of Middlesboro, south-eastern Kentucky, leaving one dead and at least two injured, ripping roofs off buildings, blowing down trees and light poles and overturning mobile homes; hail "as big as baseballs" reported in Texas, power cut to thousands of homes in Michigan, aircraft damaged at Cleveland airport in Ohio. In all, storms left one dead and 15 injured and caused damage worth "millions" of dollars. *L.L.*

14: A Boeing 747SP on a flight from San Francisco, U.S.A. to Sydney, Australia, encountered severe air turbulence over the Pacific Ocean, injuring 24 of the 172 passengeres aboard. *L.L.*

15-16June: Heatwave in northern India temperatures in Rajasthan reported to be in excess of 49°C, up to 48°C in Punjab, Uttar Pradesh and Bihar, 47°C in Delhi, the summer capitals of Simla and Srinagar reported temperatures of 32°C and 31°C, worst of temperatures at end of month, nearly 480 deaths reported. *D.T., I.H.T., B.E.M.*

16–17: Worst heatwave in 25 years reported from northern Israel, temperatures reached 105°F (40.5°C), two people died from the heat, which has also resulted in hundreds of bush fires. *D.T.*

16(reported): Floods and landslides in the Kurima district of Irian Jaya, Indonesia left nine people dead, devastated dozens of houses and flooded thousands of hectares of agricultural land, two separate incidents reported, one on February 14th, the other on March 29. *J.P.*

19(reported): Forest fires have destroyed large tracts of forest in East Germany, fires occurred due to unusually dry weather. *I.H.T.*

20–24: Torrential rains and floods in Fujian province, China, left 91 dead and over 200 injured, some 300 homes in the three counties in province destroyed, 120 bridges washed away and 400 highway sections damaged, nearly 20,000 acres of rice fields destroyed. In part of Jianyang county rainfalls reached 304mm. The level of water in major upper tributary of the Min river rose 9.15 metres above normal levels. On 23rd and 24th over 305mm of rain fell on Fogang county, Guangdong province, floods in this and four other counties left five dead and 370 injured, three others reported missing, in Fogang county 2150 houses collapsed and 6500 acres of farmland flooded. Floods in Hunan province left 32 dead and three dead in Jiangxi. *L.L.*

21–22: Cyclone "Herbie" hit a 200km long stretch of coastline of Western Australia, Australia; the m. bulk carrier *Korean Star* grounded in vicinity of Cape Cuvier and broke in two, all crew rescued. Cyclone also caused damage of $10 million to small town of Denham, roofs blown off houses, four trawlers sank and many small boats damaged, cyclone lasted three hours, no casualties reported, tidal surge also hit town; in area of town of Carnarvon damage of $10 million caused to fruit and vegetable crops, one meteorologist said that it was first time that a cyclone had hit this area at this time of year. *L.L.*

22: Several incidents reported during strong winds in England and Wales, woodland blazes reported from forest of Bere, near Waterlooville, Hants, and New Forest between Beaulieu and Brockenhurst, a total of 15 acres burned, a rather larger fire burned at Llyn Elsi, Betws-y-Coed, Snowdonia National Park, north Wales, at Morfa stadium, Swansea, south Wales, the wind upset an inflatable castle, injuring six children. *D.T., L.L.*

23–31: Storms and floods in Bangladesh, high winds and heavy rains on the 23rd left three dead and 25 others missing, all missing aboard fishing vessels sank in the Bay of Bengal; the three died in a landslide in Sylhet, rains in southern and eastern parts of country caused flash floods, and floods from the river Fenny caused floods two metres deep in towns of Khagrachbari and Banlerban; the floods throughout country washed away bridges, buildings and livestock, leaving 15000 people homeless, floods in north of country along the Brahmaputra river left at least 10 dead. *L.L., D.T.*

23(reported): Vast areas of U.S.A. threatened by drought. *I.H.T.*

27: Grassfire spread by strengthening winds destroyed and/or affected 400,000 ready cut eucalyptus rolls awaiting shipment at Los Silos forestry establishment, Rivera department, northern Uruguay. *L.L.*

29: Heavy rains touched off landslide which buried a house in Olongapo 80km north of Manila, Philippines, leaving one dead. *L.L.*

ALBERT J. THOMAS

LITERATURE REVIEWS AND LISTINGS

Book Reviews

ENVIRONMENTAL METEOROLOGY. By K. Grefen and J. Löbel. Kluwer Academic Publishers, Dordrecht/Boston/London 1988, 661pp., £84.00.

Despite the high cost of this book, its standard of presentation is actually below that which one would expect of an undergraduate dissertation. Most immediately noticeable are the frequent changes of typeface, the lack of a consistent style for maps and diagrams, plus certain errors of typing (e.g. lines half blank or too close together). More annoying in the long run, however, are the spelling mistakes and curiosities of phraseology. Thus, one is required to grapple with sentences such as "It could shown bey by different authors . . . that the influence of green is often restricted to the area itself" and "The often desriped heat island . . . is very much depending from the city size" (Katzschner's article "Urban redevelopment under consideration of climatological aspects"). While not all the articles are as bad as this, problems of spelling and phraseology are numerous enough for it to seem advisable that next time Kluwer wish to publish in English a book whose authors have a variety of mother tongues they should employ at least one editor who is a native English speaker – in this case the majority of authors are German-speaking, as are the two editors. This has also meant that, whereas the articles are in English,

the references they give are often largely in German. Consequently, there will be many who are unable to follow up specific points in the articles. While to raise this matter is to make a plea for reference lists which are linguistically more appropriate, it is also an admission of the sad fact that most English-speaking people have a poor aptitude for learning foreign languages.

The book consists of 45 papers which were given at an International Symposium on Environmental Meteorology held at Würzburg, West Germany, from 29 September to 1 October 1987. It is intended that this will be the first in a series of symposia on environmental meteorology to be held every 3 or 4 years. Hence, the book does not attempt to give an overall view of its subject. Instead, it covers a variety of topics which were presented in 5 sessions: 1) Measurement of meteorological parameters and atmospheric pollutants, 2) Dry and wet deposition, and physicochemical transformation, 3) Accidental releases, 4) Urban climate, atmospheric pollution and planning, and 5) Air pollution modelling. Articles are prefaced by an abstract and some sessions began with a review paper. All this is very helpful, since the book is of a generally advanced standard, containing plenty of numeracy, modelling, fluid dynamics, etc. To some extent personal interests will dictate which articles are judged the most useful. For this reviewer a number of ideas in session 4 proved especially stimulating (e.g. the greening of cities and attempts to provide optimum ventilation within them). Yet, all things considered, the reality is that only a few people are likely to use this book to any great extent (e.g. lecturers preparing options in atmospheric pollution and research workers seeking papers on their chosen specialism) – and very few of these will be prepared to pay £84 to purchase it.

L.T.

ATMOSPHERIC POLLUTION. By Derek Elsom. Basil Blackwell, Oxford and New York 1987. 319pp. £12.50.

Subtitled *'Causes, Effects and Control Policies'*, this book is aimed at "undergraduate students studying the atmospheric pollution problem" in Environmental, Geographical and Social Science Departments. The text makes interesting reading, firstly defining and describing the various kinds of atmospheric pollution (including noise and nuclear radiation), then addressing important political issues from Local to International level in an open-minded and uncompromising manner, while coming to some well-reasoned conclusions along the way.

The text is interspersed with 20 b. & w. photographic illustrations, but for the price, perhaps the publishers could have offered the reader at least one or two colour plates in addition to the front jacket cover, a Frank Lane Agency photograph depicting the diffusion of a plume issuing from a tall chimney stack. There are 35 tables, but some appear to be over-simplified. E.g's. (1) What were the normal 'background' death rates during the major pollution episode periods listed in Table 2.1, when 'excess death' figures are given p24? and (2) Why are at least estimated population statistics not given in Table 10.3, p236, relating noise levels to various cities? Perhaps the answer lies in the fact that most tables are *not* the author's own work. Neither are the vast majority of 75 figures, which include 2 cartoons, that liberally find adoption. To what extent has the author gone into

verifying other peoples' statistics, especially where sources are anonymous (as in Table 11.1 p.259)?

On the other hand, Dr Elsom visited China in 1985 at the PRC's National Environmental Protection Agency's invitation, and this has resulted in an inspiring sub-section (pp.230-43) on pollution control there, written with excellent first-hand insight. 'Developing' cities of high population, determined to meet higher industrial output targets and hence to advance their standard of living, can be extremely noisy and highly-polluted places.

Another example where care should be used in verifying the figures occurs in handling the London Smog episode of December 1952. Here we read that . . . "during or shortly after the four-day London smog . . . an extra 4,700 deaths occurred over and above the expected value" (p.23); a statistic repeated on p.24 and p.197. Contrast this with Meetham (1953, Weather, Vol.8, p.335) who remarked, "In Greater London the normal death rate is 2,000 per week, and it is not known who of the 4,703 and 3,138 who died in the two weeks succeeding the fog would have died anyway". Reading this, one wonders if 3,841 might be a more accurate figure for definite victims? Dr Elsom might also have mentioned that, for those interested in the meteorology, and particularly the synoptic situation which produced this rare event, an article, "The London Fog of December 5-8, 1952" by Douglas & Stewart, *Met Mag, 82,* pp.67-71, is well worth reading.

If this book is revised, perhaps more meteorology could be included in a second edition? While 24 pages of 538 references (appearing at the back) represent a considerable achievement and information source, some meteorologists would argue that the list is not 'fully comprehensive', e.g., without inclusion of contributions by Richard Scorer, such as "plumes from tall chimneys", *Weather, 10,* p.106, which was a 'classic' in its day (1955) and probably helped influence the "tall stack policy" outlined here on p.84. As it stands, "Atmospheric Pollution" contains no significant reference to the use of remote sensing and satellite imagery in determining extent and dilution of atmospheric pollutants. Prof. Scorer, in recent years, studied ship trails and oil/gas rig flares seen in photographs archived at the University of Dundee. In some cases, these pollution plumes have been remarkably persistent and very slow to spread (diffuse) sideways, on occasions up to a distance of 500km from their source. Since pollution dispersal is very much part of the problem-solving process, perhaps such interesting work as Scorer's and conclusions based on it might be included in a future revision.

Providing some of the statistics are 'taken with a pinch of salt', those who wish to seek answers to "the pollution problem" may well be stimulated by this excellent commentary into finding their own solutions on scales ranging from the local to the international. The book is well-produced, contains few typesetting/proof-reading errors (I found only one spelling mistake on p.116), and can be well-recommended for its intended purpose, especially because its open style avoids those many political pitfalls which await the unwary in this field.

W. S. PIKE

LETTERS TO THE EDITOR

THE SEVERE THUNDERSTORM OF 19 OCTOBER 1988 OVER LIVERPOOL

The thunderstorm which hit Liverpool on 19 October 1988 was one of the most violent of the last forty years and all the more remarkable for developing so late in the season.

The day dawned cloudy, but sunny periods by early afternoon raised the temperature to 17.8°C – the highest temperature of the month. winds were light, southerly.

I finished work a little early at 1620 B.S.T. (1520 G.M.T.) to drive to Knotty Ash as my mother's garden needed attention, and upon arriving at 1630 I noticed a rapid build-up of dark cloud to the west over the city centre some six kilometres distant. While getting on with the grass cutting I kept glancing at this heavy cloud to the west and saw that it was not advancing, but growing ever higher in the sky. Indeed, all the while the sky above me had stayed cloud-free.

At 1655 I heard the first rumbles of thunder. By this time the cloud had developed to a great height and become very ominous as it drifted slowly eastwards. At 1750 thunder was very loud with frequent and vivid lightning but there was little rain at Knotty ash until 1815 when all at once it became torrential and there occurred a flash of lightning and clap of thunder so loud that it was the talking point of the storm the following day. By 1840 the noise of the rain was so intense that I opened the front door and saw that all vehicles in Pilch Lane, a busy main road and bus route, were at a standstill and it was difficult to see the houses across the road.

The rain suddenly eased at 1910 so I made a dash for the car to drive home to Gateacre five kilometres south-south-east of Knotty Ash. This journey normally takes ten minutes but such was the flooding (up to a metre deep) that numerous diversions were required. Just before 1930 yet another very vivid flash of lightning and tremendous clap of thunder happened and the torrential rain set in again. My windscreen wipers could not cope, so like other motorists I just stopped. An interesting point is that my car is fitted with a German thermometer for registering the outside air temperature, and this was reading, despite the intensity of the rain a temperature of 16°C. Even at the height of summer during such a storm the temperature is often below this level. After about five minutes the rain eased a little and I continued to my flat. A dash of fifty metres from car to home and I was literally soaked to the skin, but it was either that or not getting indoors for ages. The torrential rain stopped abruptly at 2010 although lightning flickered until 2105 hrs.

A spokesman from Manchester Weather Centre said the storm developed over Liverpool and hardly moved. The Press reported falls above 50mm without stating where (information not supplied by me). At my station at Sefton Park Nurseries 56.5mm rain fell; this is the wettest spot I know about so far. Crosby Coast Guard registered 50mm (north Liverpool), Aigburth (Riversdale Technical School) 42mm (south Liverpool), and Hunts Cross 26mm (south-east Liverpool). Most of the rain fell in one to one-and-a-quarter hours in the Liverpool area. Some 20 kilometres north-east of Liverpool Barry Gratton at Hilldale measured 16mm; the thunderstorm there began as late as 21 hrs.

Around Sefton Park flooding was up to two metres deep. Our own offices were flooded by water cascading off a large school playing field. Prescot, twelve kilometres east of Liverpool had no rain, nor did the Widnes-Runcorn area. Only Liverpool and North Wirral were badly affected.

In August 1971 I registered 56.0mm at Knotty Ash during a thunderstorm and in July 1949 a similar storm dumped 54mm on Liverpool Airport (at Speke) four kilometres south-east of here. On these occasions flooding was less widespread because the really heavy rain was confined to a single rainfall station.

Sefton Park, Liverpool KEITH G. LEDSON

FURTHER NOTES ON THE LANCASTER SQUALL OF 7 FEBRUARY 1988

It may be of interest to note details of the Lancaster squall from a different aspect in order to further the evidence given by Mr David Reynolds in his paper *(J. Meteorology,* Vol.13, no.131, 284-187).

Situated at Beaumont Place (SD 477637) on the northern outskirts of Lancaster I run an amateur weather station. The site is 20 metres above sea-level and 6.5 kilometres north of the Hazelrigg station. Brief remarks compiled using my weather notes are given below.

". . . Throughout the day the wind had been south-west force 3 to 4, backing south force 3 to 5 at 1500 G.M.T. Then during the late afternoon and early evening the wind continued to veer and back between north-west and south . . . At 1850 a squall line moved from the north-west to the south-east, marking a divide between slight rain and sleet to more showery conditions. The wind veered from the south to the west, gusting to force 7 as it did so . . . Barometric pressure fell from 1008mb at 0900 to 991mb at 2100 . . .

At 2045 the main squall passed over Beaumont. This was the leading edge of a cumulonimbus cloud moving from the north-west in a south-easterly direction. The lower part of this cloud moved at an angle of 45 degrees (west to east) to the direction of movement of the cloud. Although no thunder was heard, hail did fall with some snow pellets and rain. This precipitation fell at an angle of 90 degrees to the cloud movement (south-west to north-east). At this time the wind backed to the south-west. This suggests air motion set up within the cumulonimbus by a strong updraught, sucking the precipitation towards the centre of the cloud mass . . .

The hail lasted from 2045 to 2052 G.M.T. The average diameter of the hail was 6mm and the maximum diameter 11mm (0 to 1 on the TORRO Hail Intensity Scale, with size code 1 to 2. Webb, J. D. C. *J. Meteorology* vol.13, 129, 166-167). The hail accumulated in patches to a depth of 10mm, but soon thawed. The screen temperature fell from 3.1°C at 1800 to 1°C by 2050, while the ground temperature fell from 2.8 to 0.1°C. The wind was not as strong as at Hazelrigg but did gust up to force 8 during the shower. As the clouds moved away to the south-east the wind veered to the west and north-west, and bright trails of precipitation were observed falling at 90 degrees to the cloud movement".

Hazelrigg would have missed the bulk of this shower by only five kilometres whereas Beaumont missed the unusual gust.

Two days later on 9th February 1988 a damaging gust felled a tree blocking the A6 on Beaumont Bridge (SD 476637) for three hours. The gust was measured by a ventimeter. I was lucky enough to be taking readings at the time! Using the appropriate corrections for height the gust reached 71 m.p.h. or force 11 at 1740 G.M.T. Hazelrigg had a gust of 74 m.p.h.

34 Beaumont Place, Beaumont, Lancaster DAVID EVANS-RUSH

OCTOBER DELUGE IN SOUTHERN IRELAND

After a disappointing summer in Ireland which saw only a few weeks of good weather in June people were hopeful of a reasonably good autumnal spell of weather. However this season of "mists and mellow fruitfulness" could well be described as "of deluges and stormy windiness" by the people of south-west Ireland. September was mainly a poor month with a brief dry spell in the middle, and a rainy end continued into October. Frontal systems became ever more vigorous and falls of rain of 10 to 25mm occurred on many days in the first nine days and also towards the end of the month, but it was on the 10th October that the first deluge struck.

An active low moved quickly south/south-east from south-east of Greenland during the 10th, and by late evening was near Valentia, with a central pressure of 990mb and heavy rain moving into Kerry, Cork and Limerick. This covered much of southern Ireland by the morning of 11th. At 0900 on 11th my station on the northern foothills of the Ballyhoura Mountains on the Cork-Limerick county boundaries had received 58.6mm with 60mm at Roches Point, County Cork, and over 35mm at Valentia. Flooding was widespread all across County Cork. However, the following days saw much less rainfall which allowed residents to mop up. Nevertheless, worse was to come on 20th when a low approached rapidly from the Azores.

As it passed by the south-west of Ireland torrential rain accompanied by strong to gale-force south-east winds spread into south-west Ireland overnight, and continued well into 21st. At 0900 G.M.T. most rainfall stations in Cork and Kerry had over 50mm. My station had 49.1mm with a further fall of 26.5mm in the following seven hours: total 75.7mm. In the west of County Cork things were much worse. Ballingeary had up to 125mm of rain in 32 hours, and the adjoining mountains probably much more at monthly-read gauges in the Boggaragh Mountains. This additional heavy rain meant that the River Lee rose to dramatic levels largely because the hydro-electric dam downriver at Inniscarra was unable to release the floodwaters quickly enough. An E.S.B. spokesman put the rate of water entry to the reservoir behind the dam as over 500 tonnes of water per second with a discharge rate of 250 tonnes per second at maximum. Many towns were flooded, and in the south-west all over the Munster region farmland is in a very soft condition forcing farmers to take the stock off the land to avoid poaching and in most cases to allow cattle a dry place to rest. This will increase the demand for winter fodder which the stock must be given when they are off pasture.

Mount Russell, Kilmallock, Co. Limerick, Eire DAVID MESKILL

GRANT INSTRUMENTS' VERSATILE NEW WEATHER STATION

Compact and easy to install, the new Squirrel Mini-Met weather station from Grant Instruments can be left unattended on-site for up to one month to monitor a comprehensive range of meteorological parameters. The versatile Mini-Met is based on Grant's tried and tested Squirrel 1201 data logger, and comes complete with high-quality sensors for measuring and recording temperature, relative humidity, solar radiation, wind speed, wind direction and rainfall. Alternatively, customers can build a system suited to individual requirements with their own choice of sensors from the range.

Mounted inside a lockable, weatherproof IP65 enclosure, the Squirrel has four inputs for temperature and two for relative humidity. Relative humidity probes are fitted with a louvred shield to protect them from radiation and rain. Four voltage channels are available for use with a solarimeter, wind vane or any sensor with a suitable voltage or current output. Two pulse count channels accept inputs from a switching anemometer and a tipping bucket rain gauge. The Mini-Met 12-bit Squirrel features simple push button operation, and takes averaged readings of all channels at user-selected intervals. At the end of a recording run the Squirrel can be removed for data analysis back at base. Alternatively, data can be downloaded on-site using an IBM PC compatible lap-top computer and Grant's transfer/analysis software.

The Mini-Met enclosure and sensors are mounted on a mobile stand, making transport from site to site a one-man operation. When the assembly has been firmly anchored to the ground, the stand's wheels can be easily removed.

Grant Instruments Ltd, Barrington, Cambridge, CB2 5QZ (telephone 0763 60811, fax 0763 62410).

WORLD WEATHER REVIEW: June 1988

United States. *Temperature:* mostly warm (including Hawaii); +6degC in E. Montana, N.W. Dakotas, N.E. Wyoming; hottest June for over 50 years in this area. Cold near E. and s. coasts and W. to S.E. New Mexico; S. California, Washington state; -1degC locally in all these areas. *Rainfall:* wet only near N.W. coast S. Louisiana, C. Texas, in and near New Mexico; various small areas. Over 200% in N. California, N.E. Arizona to S.E. New Mexico; C. Texas, S.E. Louisiana. Dry elsewhere; under 50% general from Montana to N. Florida and S. New Hampshire; also S. California, S. Nevada, S.W. Arizona, S. Texas, Hawaii. About half this area had under 25%, and it was the driest June on record in much of the eastern half of the country.

Canada and Arctic. *Temperature:* warm in Alaska and most of Canada; N.E. Greenland to Franz Josef Land; N.E. Iceland; +6degC in S. Saskatchewan. Cold in coastal British Columbia, Quebec, Labrador, Maritime Provinces, S. Iceland, most of Greenland; -2degC in much of Quebec. *Rainfall:* wet from W. Alaska through Great Slave Lake to N. Alberta, N. Baffin Island, Greenland, W. Iceland; Labrador, Newfoundland, Nova Scotia. Over 200% from N. Alberta to N. Greenland; E. Newfoundland. Dry elsewhere; under 50% on coast of Beaufort Sea; S.E. Saskatchewan to Great Lakes and S. Baffin Island.

South and Central America. *Temperature:* warm in extreme N.W. and C. Mexico and from S. Mexico to Honduras; locally in C. Argentina and C. Brazil (all locally +1degC); Bahamas. Cold elsewhere in Mexico and in almost all of South America 15-40°S.; -2degC from Uruguay to S. Paraguay; locally in W. Bolivia, C. Chile and N. Mexico. *Rainfall:* wet from C. Mexico to Honduras; locally in coastal S. Brazil and interior C. Argentina; Bahamas. Over 200% in S. Guatemala, Bahama, coast near Rio de Janeiro. Dry in N. Mexico and nearly all of South America 15-40°S. Under 50% in N.W. and N.E. Mexico and from E. Brazil through Bolivia to C. Chile, C. Argentina and Uruguay.

Europe. *Temperature:* warm in Scandinavia, European Russia (except W. Ukraine), Sardinia, British Isles (except S.E. England), coastal W. France; locally from S.E. Romania to Greece; +2degC from E. Norway to C. and S. Urals; +4degC near Perm. Cold elsewhere; -2degC in C. Spain. *Rainfall:* wet from Finland and W. European Russia to E. Germany, W. Czechoslovakia, N. Romania and parts of Hungary; S. Jugoslavia, S.W. Bulgaria, Italy (except extreme S.), Spain, Portugal, S.W. France. Over 200% in most of Spain and Portugal, widely in W. European Russia and locally in Poland and N. and C. Italy. Dry elsewhere; under 50% from much of Great Britain and parts of Ireland to N. France, Belgium, Netherlands and much of Scandinavia (except most of Finland); E. and N. European Russia, Greece; locally in S. Czechoslovakia and W. and E. Hungary. Provisional sunspot number 102 (May: 60).

Africa. *Temperature:* mostly warm N. of Sahara; Botswana, Transvaal; +1degC widespread except in Transvaal. Cold in Morocco, interior Tunisia, parts of N. Algeria; S. Namibia, Cape Province, most of Orange Free State; -1degC at least locally in all these areas. *Rainfall:* wet in coastal W. Morocco, N. Tunisia and much of N. Algeria; S. Zimbabwe to Netal; locally in Cape Province; over 200% in all these areas, especially S. Zimbabwe to Natal. Dry generally N. of Sahara; most of Namibia and Botswana; much of Cape Province; under 50% widespread in all these areas.

Asiatic U.S.S.R. *Temperature:* mostly warm; +3degC N. of Kamchatka and in lower Amur basin; +4degC in W. Kazakhstan and near Sverdlovsk. Cold in Yenisey and E. Ob basins and on coast of East Siberian Sea; -4degC in upper Yenisey basin. *Rainfall:* mostly wet; over 200% N. and E. of L. Baikal and in W. Kazakhstan. Dry from Urals and upper Ob basin to E. Kazakhstan; lower Lena, Kolyma and lower Amur basins; S. Kamchatka. Under 50% in all these areas, especially Urals to E. Kazakhstan.

Asia (excluding U.S.S.R.). *Temperature:* warm in W. Turkey, S. Pakistan, W. and S. India, E. Bangladesh, most of China; Korea, Japan, Thailand, Kampuchea, C. and s. Laos, Sarawak, Philippines; +2degC in S. China. Cold in most of Turkey; N. Pakistan, N.E. India, W. Bangladesh, interior N. China, Mongolia, N. Laos; -2degC in N.E. India. *Rainfall:* wet in Turkey (except S.W.), N. Pakistan, N. India, Bangladesh (except N.W.), W. and N. China, N.E. Korea, S. Japan; most of Thailand and Malaya. Over 200% locally in last four areas; widely in C. and E. Turkey; near Calcutta; parts of N. China. Dry in S.W. Turkey, Middle East to most of Pakistan, India and N.W. Bangladesh; E. and much of S. China, Korea (except N.E.), N. Japan, Sarawak; locally in N. Thailand. Under 50% at least locally in all these areas (except perhaps Bangladesh), especially S. Pakistan, S. India, E. and S. China. Middle East mainly rainless. Philippines near normal.

Australia. *Temperature:* warm almost everywhere (but -1degC in N.E. Queensland); +2degC in and near W. Queensland. *Rainfall:* wet in S.E. (except S.E. coast) and extreme S.W.; over 200% N. of Brisbane; otherwise mainly unde 50%.

M.W.R.

WEATHER SUMMARY: August 1988

Mean temperatures were again rather below normal over England and Wales, by as much as one degree Celsius locally in southern coastal areas. Scotland on the other hand saw mean values very close to the August average. In almost all parts of the U.K. temperatures reached their highest levels on 7th and 8th, rising to 30.2° in the Carlton area of Nottingham and 29.9° at Great Malvern (Hereford and Worcester) on 7th and to 27.3° at Abbotsinch (Glasgow) and 26.4°C at Inverdruie (Highland) on 8th. Various parts of central Scotland reported minima of around 15° on 5th and 6th while on 8th Ilfracombe (Devon) recorded 18°, Guernsey 17.7° and Buxton (Norfolk) 17.2°C. On 29th a maximum of 10.3° was recorded on the Ochil Hills in central Scotland and on 25th High Bradfield (South Yorkshire) recorded just 10.6°. Low minima included -0.5° at Dall (Rannoch School) and 0.8° at Tummel Bridge (Tayside) on 22nd, 0.6° at St. Harmon (Powys) on 16th and 3.6°at Gurney Slade (Somerset) on 22nd. On the grass the

temperature fell to –3.4° at Laurieston (Dumfries and Galloway) on 21st and to –2.2°C at Cellarhead, near Stoke on Trent (Staffordshire) on 3rd. Rainfall was above average in many northern and western areas of the U.K., between 150 and 200 percent of the normal falling in a number of places, while central and south-eastern areas were mostly on the dry side, particularly in the far east of East Anglia and Kent where some stations received less than 50 percent of their normal rain. High daily totals include a reported 65.6mm at Weston-super-Mare (Somerset) during overnight thunderstorms on 19th, 58.2mm at Coniston (Cumbria) and 39.6mm at Nantmor (Gwynedd) on 13th and 50.4mm at Torquay (Devon) and 45.3mm at Royston (Cambridgeshire) on 31st. In south Wales 43.2mm fell at Carmarthen (Dyfed) on 17th. Sunshine totals were rather above the normal in many central and eastern counties of both England and Scotland but mostly below in northern and western parts where it was especially dull locally.

Although the month started unsettled with rain in places and with some scattered thunderstorms on 2nd, generally the first week of the month was dominated by a ridge of high pessure that built from the south-west across southern and central Britain. This culminated in the highest temperatures of the month before unsettled conditions returned from the west again on 9th. As a succession of frontal systems moved eastwards across the British Isles the next few days were changeable with showers or longer spells of rain, some of the rain being heavy in the west and north. Southern Britain had a dry day on 15th as a ridge of high pressure spread into the country and, after a cool start, the 16th was another sunny day over England and Wales. South-eastern Britain remained sunny and quite warm on 17th and 18th but western areas had some rain at times and some outbreaks of heavy rain spread to the rest of Britain by end of 18th. Cooler, unsettled weather spread to all parts on 19th, under the influence of a complex low pressure area over Scotland, and the 20th was much cooler and showery in all parts. After further showers on 21st the next couple of days were cool and dry with local ground frost at night, particularly in the north, but rain returned to many parts on 23rd as the ridge of high pressure moved on into Europe. Although frontal systems crossed the country over the next few days they were very weak in the south and the south-east remained mostly dry and warm until 31st when some heavy and locally thundery rain spread to much of the south-east.

K.O.M.

TEMPERATURE AND RAINFALL: AUGUST 1988

	Mean				*Grass*					
	Max	*Min*	*Max*	*Min*	*Min*	*Rain*	*%*	*Wettest*	*RD*	*Th*
BELGIUM: Uccle	22.0	13.0	27.3(8)	8.3(4)	2.5(4)	78.1	106	16.0(24)	17	–
„ Rochefort	22.3	9.5	29.2(7)	4.6(17)		41.9	53	9.8(24)	12	–
„ Houwaart	24.2	10.6	29.8(18)	5.2(4)		45.2	58	11.2(11)	14	4
DENMARK: Fanø	17.9	12.9	23.8(9)	8.2(24)		95.7	126	12.3(20)	19	4
„ Frederikssund	20.9	12.8	27.0(10)	9.8(23)	7.8(23)	87.3	131	29.2(12)	17	2
GERMANY: Berlin	22.8	12.3	29.3(15)	7.5(4)	6.6(4)	21.5	31	8.8(3)	11	2
„ Hamburg	21.4	12.2	27.3(9)	6.7(18)	3.7(18)	57.0	68	23.1(21)	15	3
„ Frankfurt	25.3	13.3	31.4(8)	7.0(4)	4.8(4)	32.4	44	13.1(11)	11	4
„ Munchen	23.8	12.1	32.0(14)	5.2(5)	3.6(5)	117.1	105	32.8(20)	16	6
ITALY: Casalecchio	29.9	19.4	37.0(15)	13.0(24)	12.0(24)	6.0	21	5.0(23)	2	2

	Mean				*Grass*					
	Max	*Min*	*Max*	*Min*	*Min*	*Rain*	*%*	*Wettest*	*RD*	*Th*
MALTA: Luqa	32.3	22.6	36.2(16)	20.1(28)	16.1(12)	trace	0	trace(9)	–	1
NETH'NDS: Ten Post	20.7	12.2	26.1(6)	8.2(3)	3.6(27)	114.8	129	37.6(22)	15	7
„ Schettens	19.9	12.8	25.3(18)	8.8(3)	3.8(3)	67.7	83	13.6(26)	14	7
„ De Bilt	21.7	12.0	27.1(18)	6.9(17)	3.3(17)	62.0	70	20.6(25)	14	4
„ Lemmer	20.0	12.1	25.4(28)	8.5(3)	7.1(3)	138.5	160	50.8(21)	13	5
NORWAY: Donski										
SWEDEN: Valla	20.3	10.5	23.8(6)	6.1(25)		78.6		13.1(22)	20	7
SWITZ'LAND: Basel	25.3	13.6	32.7(14)	8.5(31)		92.9	99	24.4(20)	15	13
EIRE: Galway	17.1	11.6	23.7(7)	9.0(18)		145.2	148	19.0(18)	28	–
„ Straide	17.1	10.5	22.7(7)	3.4(1)	–2.5(1)	121.4	124	17.9(31)	26	1
SHET'AND: Whalsay	14.4	10.1	16.8(6)	6.0(2)	1.6(2)	117.3	195	21.8(14)	24	0
„ Fair Isle	13.2	10.1	15.1(27)	7.4(25)	1.8(25)	115.3	196	20.4(18)	21	1
SCOT'AND: Braemar	16.0	8.6	22.8(7)	3.7(26)	2.0(26)	95.9	115	12.4(19)	25	0
„ Inverdruie	17.7	8.5	26.4(8)	4.0(10)	–0.1(10)	96.3	108	15.0(12)	22	1
„ Rannoch	16.8	9.4	24.0(6)	–0.5(22)	–0.5(22)	108.0		15.0(20)	21	–
WALES: Pembroke										
„ Velindre	18.7	10.3	27.0(7)	4.0(16)	0.0(3)	73.0	103	20.5(30)	17	0
„ Carmarthen	17.6	11.2	26.1(7)	5.5(16)	–0.6(16)	213.3	185	43.2(17)	21	0
„ Gower	18.1	11.9	25.6(7)	8.4(16)	4.7(16)	168.6	165	28.7(17)	21	0
GUERNSEY: Airport	18.8	12.9	25.7(7)	10.7(15)		71.3		24.4(31)	14	1
ENGLAND:										
Denbury, *Devon*	19.5	11.1	24.6(7)	7.6(22)	5.4(22)	90.0	146	35.9(31)	16	0
Gurney Slade, *Somerset*	18.7	9.3	28.3(7)	3.6(22)	3.0(22)	80.5	61	15.4(18)	19	0
Yatton, *Avon*	20.0	11.6	29.5(7)	5.0(3)	4.0(22)	105.6	134	18.1(31)	19	1
Corsham, *Wiltshire*	19.6	11.1	29.0(7)	6.8(3)		83.7		23.5(31)	18	1
Mortimer, *Berkshire*	20.4	10.7	28.7(7)	6.3(3)	2.6(3)	60.6	95	13.0(6)	11	1
Reading Univ., *Berks*	20.3	11.0	28.0(7)	7.7(16)	2.0(29)	52.1	98	16.9(31)	11	1
Sandhurst, *Berkshire*	21.1	10.4	28.3(7)	5.5(3)	3.3(3)	49.4	86	29.4(31)	9	1
Romsey, *Hampshire*	21.1	10.3	28.9(7)	5.7(29)		61.4	94	31.5(31)	15	0
Horsham, *Sussex*	21.3	10.7	27.9(7)	4.5(29)	2.0(29)	34.9		12.9(18)	14	1
Brighton, *Sussex*	20.3	12.1	28.0(7)	8.3(29)		46.6		19.4(18)	14	0
Hastings, *Sussex*	20.1	12.6	26.2(7)	10.0(v)	7.4(3)	43.4	86	18.4(18)	12	2
Dover, *Kent*	20.7	12.1	26.0(6)	7.4(3)		27.5	44	14.5(18)	11	3
East Malling, *Kent*	21.3	11.6	27.2(6)	8.3(17)	4.3(17)	31.2	55	9.3(24)	9	1
Epsom Downs, *Surrey*	20.9	10.6	28.6(7)	6.1(3)	3.7(29)	53.3	92	25.7(31)	12	2
Reigate, *Surrey*	21.4	11.1	28.5(7)	6.2(29)		41.6	66	20.7(31)	12	1
Guildford, *Surrey*	20.7	12.0	28.4(7)	7.9(29)	5.1(29)	54.0	99	24.9(31)	11	2
Sidcup, *London*	21.8	12.2	28.2(6)	8.6(3)	5.3(29)	43.4	76	25.4(31)	8	1
Hayes, *London*	21.2	11.9	29.0(7)	8.0(29)	5.4(29)	51.4	97	31.0(31)	12	2
Hampstead, *London*	20.5	12.2	26.8(7)	8.2(29)	4.2(3)	56.7	76	18.7(31)	12	3
Royston, *Hertfordshire*	21.3	11.9	29.0(7)	8.2(3)	5.5(3)	59.0	100	45.3(31)	12	1
Loughton, *Essex*	21.3	11.8	26.9(7)	8.0(29)		37.5		19.1(31)	12	2
Buxton, *Norfolk*	21.3	11.4	26.5(6)	6.0(17)	4.5(17)	33.6	65	17.8(31)	10	1
Ely, *Cambridgeshire*	21.4	10.2	28.7(7)	6.0(3)	5.2(29)	62.5	116	44.7(31)	13	2
Luton, *Bedfordshire*	21.1	10.8	28.9(7)	5.9(3)	0.4(23)	68.3	110	23.1(30)	13	2
Buckingham, *Buck'shire*	20.5	10.1	28.8(7)	5.6(16)	0.0(16)	46.0	83	19.6(31)	15	0
Oxford University	20.4	11.9	28.2(7)	7.6(3)	3.7(3)	38.8	66	15.3(31)	14	–
Stourbridge, *W.Midla'ds*	19.5	10.9	26.9(7)	6.6(v)		69.0		17.8(27)	14	0
Wolverhampton	18.9	10.8	28.0(7)	7.9(3)	4.4(3)	67.2		18.6(27)	16	0
Kettering, *Northants*	21.0	11.2	28.8(7)	5.6(16)		48.8		17.5(31)	15	1
Louth, *Lincolnshire*	20.6	11.6	27.0(6)	7.7(2)		51.8		11.0(28)	15	3
Nottingham *Nott'shire*	21.0	11.4	30.2(7)	7.2(16)	5.8(16)	33.5	53	6.7(11)	15	0
Middleton, *Derbyshire*	17.0	10.2	24.5(7)	7.0(29)		105.1	122	21.3(18)	21	1
Keele University, *Staffs*	18.3	10.1	27.4(7)	7.1(16)	0.1(26)	80.9	96	16.6(18)	17	0
Liverpool, *Merseyside*	19.1	11.6	27.8(1)	8.1(16)		95.2	111	20.4(18)	18	2
Lathom, *Merseyside*	18.5	11.7	26.9(7)	8.6(2)		88.0		20.9(18)	17	–

	Mean Max	Mean Min	Max	Min	Grass Min	Rain	%	Wettest	RD	Th
High Bradfield, *S.Yorks*	15.7	9.9	23.3(7)	7.7(22)		81.1		21.8(18)	20	-
Cottingham, *Humb'side*	21.1	11.7	27.0(7)	7.3(2)	4.1(2)	58.9	83	13.5(2)	15	3
Carlton-in-Cleveland	19.1	10.9	27.3(7)	7.3(2)	4.8(1)	64.5		20.8(18)	15	0
Durham University	19.3	10.2	26.3(7)	6.9(1)	4.0(31)	46.0	67	12.9(18)	15	-
Sunderland, *Tyne/Wear*	18.8	11.9	22.5(17)	9.4(2)		48.5	76	12.8(18)	15	1
Carlisle, *Cumbria*	17.9	11.4	25.9(8)	6.1(2)		123.0	143	22.8(19)	19	1
CANADA: Halifax	22.8	14.2	30.2(5)	8.9(22)		36.9	38	9.8(26)	14	0
U.S.: Bergenfield, *NJ*	29.8	19.3	36.1(13)	10.0(22)		47.2		29.2(24)	5	4
AUSTR'LIA: Leopold	15.0	6.3	19.5(15)	2.5(12)		55.5	102	29.0(16)	9	1

CUMBRIA RAINFALL:

Gillerthwaite, 338.0mm (172%); The Nook, Thirlmere, 305.8mm (158%); Coniston, 347.1mm (175%); Hawkshead, 229.1mm (154%); Appleby, 76.0mm (96%).

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compiled by K. O. Mortimore

JOURNAL OF METEOROLOGY Vol. 13, no. 134, December, 1988

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Grant Instruments' Squirrel Mini-Met Weather Station.

EDITORIAL OFFICE:
Journal of Meteorology, 54 Frome Road, Bradford-on-Avon, Wiltshire, BA15 1LD, U.K. (telephone: 02216 2482).