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POSSIBLE BALL LIGHTNING COLOUR PHOTOGRAPH FROM SANKT GALLENKIRCH, VORARLBERG, AUSTRIA

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Abstract: A resident of Sankt Gallenkirch, Montafon, Vorarlberg, Werner Burger, reported a colour diastide of ball lightning taken in 1978. A field investigation by the author and four expert witness reports (astronomy, pyrotechnics, lightning protection, computerized photo valuation) ruled out a meteor, fireworks and ordinary lightning. The case is open to further hypothesis testing. Following press publicity, 17 more ball lightning reports emerged from the vicinity.

INTRODUCTION

In the history of ball lightning studies, photographic cases promising some kind of physical evidence have been highlights and pitfalls. Highlights such as the US Prairie Network ball lightning photograph (Barry, 1980, 97-98) are rare. Pitfalls are more numerous, e.g. of 24 alleged kugelblitz pictures examined by Barry (1980, 79-131), only a handful survived. What is true for the spectacular Ashford video tape (Meaden, 1990; Bergstrom and Campbell, 1991) was also the research motto for the Austrian case: *never trust attractive optical evidence*. A preliminary study is finished now, and case details and analytical steps are presented extensively here to give *J. Meteorology* readers an opportunity to develop their own hypotheses.

Werner Burger, eyewitness and photographer of the colour slide contacted the author after a press call for reports in early 1990. He sent glossy copies in summer, and in September 1990, Keul went to Vorarlberg for a field investigation. The case remained interesting, so copies of the photograph plus reports were distributed to four experts asking for their opinions on astronomical, pyrotechnical, and atmospheric electric aspects and submitting the photograph to a computer-based enhancement and image analysis. In spring 1991, all four reports had been sent to the author. The case was released to the Austrian press in the summer. This resulted in 17 additional ball lightning reports forthcoming from local residents. Two more field trips were done to interview witnesses.

VISUAL OBSERVATION AND PHOTO-TAKING SITUATION

On a summer night of 1978 (date not known) Werner Burger watched an

approaching squall line at Sankt Gallenkirch, Vorarlberg Federal Province (western Austria) at about 10°E longitude/47°N latitude and 900 meters above sea level. Sankt Gallenkirch has 1400 inhabitants and 2000 tourist beds. It lies in the Montafon Valley of southern Vorarlberg, surrounded by mountain ridges of over 2000 metres. The observation point was Mr. Burger's parents' house at Aussergant, beside the Montafon through-road. Burger screwed his reflex camera (plus wire-release) to a tripod and went out on the balcony to make time exposures of lightning flashes. The camera faced Mt. Grappeskogel (2206m), a mountain in the east. It was dark and before midnight.

Burger was just taking another time exposure, so the camera shutter stood open and the wire-release was pressed down, when he heard a peculiar sound, suddenly, "like a Christmas sparkler or a wire-brush moved over an edge (intermittently)". Then, just ahead, "a fireball fell down" and Burger – somewhat shocked – let go the wire release before the object actually disappeared. When asked to re-imagine the course of events with his eyes closed, the witness gave a time estimate of three seconds total duration with two seconds visual observation time (repeated stop-watch readings). The "fiery" object seemed to drop "in free fall".

The 1978 lightning photographs were taken with a one-year old Fujica AZ 1 reflex camera, with a Fujinon lens 1:1.8; f55mm, 30mm front lens opening. The camera focus was set to infinity, the exposure handle to "B" (time exposure). The f stop is unknown (range: 1.8 to 16), use of a skylight filter possible. The camera was mounted on a simple movie-camera tripod, so a blurring of the photo could not be ruled out. The photographic material was an AGFA (Western Germany) CT-18 50 ASA colour slide film which is no longer manufactured now. The slides were developed soon after the exposures. The alleged ball lightning photograph has running number 16/17 on the film roll. Burger still keeps slides no.26/27, 28/29 and 32/33 of this film showing lightning strokes. The overexposed rest were thrown away.

LOCATION, DATE AND WEATHER

The Mt. Grappeskogel summit (2206m), measured with quadrant and compass from the observation spot, has 25° elevation and 100° azimuth (nearly east). As the summit forms the centre of the three linear lightning photographs and Burger said he did not move the tripod, it can be assumed that the camera axis also pointed that way when the kugelblitz fell. The terminal fall area – open farmland and meadows – lies behind a neighbour's house, trees and a pole of the local power line (visible on the lightning photographs; see Figure 1 for a rooftop view).

The witness guessed from notes on his 1978 slide-cassette that the photographs had been taken between April and September. It was dark, around midnight, the sky overcast. When the squall line passed over the location, some rain fell. Otto Svabik from the Climatology Department of the Central Meteorological Office, Vienna, a study colleague of the author, helped by



Figure 1: Terminal fall area of the kugelblitz with Grappeskogel in the background. View from rooftop of the Burger boarding house (neighbouring building to parents' house).

scanning the climatological records of three Vorarlberg stations – Bürs near Bludenz, Vandans and Partenen. Thunderstorm observations were made on July 9/10, August 3/4 and 6, 1978. According to Svabik (1991), the August 3/4, 1978, night thunderstorms probably were the date of the ball lightning case: "A thunderstorm front crossed Austria at that time, causing widespread damage". Rainfall was 6mm at Vandans and 1mm at Bürs.

WITNESS AND FORENSIC PSYCHOLOGY

Werner Burger, born in 1957, is currently employed by the Bludenz district court. With his wife Anneliese he runs a tourist boarding house. The family has three children. In 1978, Burger was working for the Silvretta cablecar company. Burger's eye-sight is normal. He likes to paraglide, climb and photograph in his free time. From tales of his grandfather, he knew a bit about ball lightning. He showed the diastide to several people who could not identify it, so it eventually went into the drawer for 12 years.

Is it possible to keep a precise memory about a few seconds of a chance observation 12 years ago? Forensic psychologists have done numerous experimental studies about eyewitness testimony, but on other contents, situations and latency periods (time lag between observation and memory situation) than ball lightning. Some interesting findings of this research tradition are: Outstanding details of an action sequence are remembered

excellently (98%; Marshall, Marquis and Oskamp, 1971). Central details of an action scene are reported clearly even when they caused fear (Kebeck and Lohaus, 1986). Persons tend to overestimate the duration of fear- and stress-loaded events (Sarason and Stoops, 1978). Observed details can be distorted by suggestive questioning upon retrieval (Carmichael, Hogan and Walter, 1932) as well as by personal and cultural stereotypes. Emotionally upsetting, consequential events are often memorized together with irrelevant details of the event situation ("flashbulb memory"; Brown and Kulik, 1977). Falsely remembered details are consistently memorized in this wrong way ("freezing effect"; Kay, 1955).

To escape the Carmichael et al. distortions, the author gave no clues at all when doing the field interview. Mr. Burger showed a "flashbulb memory" remembering the smell of apples his mother had cut in the kitchen when he came in again after his observation at the balcony. A possible source of error is the overestimation of stressful event durations.

ANALYSIS OF THE PHOTOGRAPH

The original diaslide frame measures 23 x 35mm (Figure 2). It is different from Burger's three bluish-violet, overexposed linear lightning slides by having no clear background. Above a dark and blurred bottom line and a central, diffuse "cloud", a curved light trail runs from the left upper corner down to the middle of the frame, starting faintly, then shooting out "sparks" to the left, flaring up and terminating suddenly (the witness, shocked, released the shutter).



Figure 2: Paper print of the possible ball lightning colour slide taken by Werner Burger, Sankt Gallenkirch, Austria. Because of irradiation in the duplicating process the background is much darker than in the original photo.

Contrary to most ball lightning cases, we here have a colour photograph as back-up. The photograph analysis was meant to clear up the following questions:

1. Are there hints for a solid luminous object?
2. Are there distance cues to be used as size cues?
3. What is the information to be extracted from the faint luminous trail and the "sparks"?
4. Could this be a fireworks rocket? Why (not)?
5. Is this an astronomical phenomenon? Why (not)?
6. Is this an ordinary lightning discharge? Why (not)?

These questions together with case data, contact and paper copies of the photograph were handed over to the expert witnesses.

Firstly there is the written expert opinion of Dr. Zdenek Cepelcha, senior meteor-astronomer with great experience in interpreting meteor photos, Ondrejov Observatory, Czechoslovakia (1990):

- "1. The strongest indication that it is a solid body obeying gravity field is the near parabolic shape of the fainter trail . . .
2. If the dimension of the fainter main trail was 10cm, it was 40m away from the camera. If the dimension was 1m, it was 400m away . . .
3. The shape of the sparks has certainly nothing to do with an assumed 'motion of the camera'. Even the two longest and brightest sparks have different trajectories . . . the good focus . . . speaks for a quite stable camera . . .
4. There is no reason why it could not be a firework rocket. There are types with retarded explosion.
5. Certainly – it is not a fireball (bright meteor – A.K.) trail."

Secondly, there is the verbal expert opinion of Claus Feuerstein, pyrotechnist of a Salzburg fireworks company (1990) who responded to the question 'Could this be a fireworks rocket?':

"Actually not. Fireworks rockets have a propulsion part with magnesium powder, like Christmas sparklers, and an effect portion. There are propulsion parts with 'comet ascent', but this is not the case here; here the head is burning, which is completely unusual with fireworks objects. The trail, too, does not fit in with fireworks. Such 'sparks' are not present in pyrotechnics, . . . military-like . . . Drops with an afterburn, . . . like burning gas or liquid, ignited, thrown out, flaming up."

Next is the verbal expert opinion of engineer Alfred Gugenbauer, sworn expert witness for lightning protection, senior of the Upper Austrian Lightning Protection Society, Linz, Austria (1990) about the question 'possible connection with an ordinary lightning stroke': "The ramifications point towards lightning, also the way-off luminous structures . . . It looks like an upward lightning stroke – straight line and ramifications . . . The [upper] 'trail' then would be an ionization current of 100-200 Amperes, . . . a long-time current . . . It surely was a lightning process, the ramifications are specific . . . nearby, the sound is typical, plus a sharp bang. I suppose it to be an upward lightning phenomenon. Great, that he got it as he did".



Figure 3: Computer-enhanced image of the possible kugelblitz track, "sparks" and flaring, produced by Peter Marx, UCLA.

Here is the written expert opinion of Dr. Peter Marx, Image Processing Scientist [professional photographer, systems analyst and image processing expert of medical scans], Department of Medicine, UCLA, Los Angeles, USA (1991):

"[The] color 35mm slide [was] digitised using a high resolution scanner (Barneyscan . . .) into a[n Apple-] Macintosh computer. The digitized image was then processed through a variety of software applications, including Spyglass Transform and View, NIH Image, and GreasePencil. The processing types included high-pass filtering, contour mapping, gray-scale and component transforms, histogram analysis, windowing, and other filtering. The resulting images are discussed below.

1. Examination of the original image demonstrated a long process starting in the upper left corner and proceeding into the luminous object. This process was enhanced via window width and level changes to produce [Figure 3] . . . The

image intensity of the process is approximately 12% different from the process's surroundings.

2. The inner area of the luminous object is demonstrated in [Figure 4]. The area was selected via a contour-following tool that determines the boundaries based upon a percentile change in pixel intensities. Using histogram equalization and windowing, the inhomogeneity of the inner region was then enhanced as shown. The image intensities within the inner area differ by less than 3% throughout the area.

3. The object's surrounding area (outside of the inner area and above the background threshold) is shown in [Figure 5]. This figure is a contour map of the entire image with the levels set to 91, 142, 183, 224, and 255 (from red, green, and blue components, each utilizing an 8-bit scale ranging from 0 to 255). This resulted in a map [which] demonstrated a 'multiple halo' effect of the inner area; there are three distinct contours shown, not including the innermost one. Note that there is an effect resembling turbulence in the upper left side of the image . . . The images are uncalibrated without references and the only morphometric analysis that can be performed is one based upon pixel counts . . . Finally, a note about the striations shown about the inner area; these patterns are common in photographs with flaring . . . the small, bright processes leading away from the inner area are diffuse and ill defined, perhaps due to their high speed relative to the shutter speed. Note that the long process leading



Figure 4: Computer-enhanced inner area of the possible ball lightning flaring process, produced by Peter Marx, UCLA.

from the object to the upper left . . . is relatively well defined, leading to the conclusion that the photographer [or, rather, the tripod – A.K.] was steady during the exposure.”

DISCUSSION

Does the Sankt Gallenkirch case fit in with other Austrian kugelblitz data? A statistical evaluation of 150 Austrian cases (Keul and Schwarzenbacher, 1989) showed 80% summer observations, a 70% thunderstorm connection, more than 90% single-object events and about 70% durations up to five seconds. The median of the reported diameters is 25 centimeters. 60% of the objects were red-orange-yellow, 14% emitted “sparks”. Therefore, the photographic and visual case details from Vorarlberg are “good average”.

The photo-analysis cleared up some points in question: Meteor astronomer Cepelcha ruled out a bright meteor [in front of the clouds?] and estimated the “faint trail” cross-section to be one metre for a distance of 400 metres. Pyrotechnist Feuerstein said it was no standard fireworks rocket. Computer image analyst Marx, after enhancement of the photograph, described a multiple halo effect and turbulence signs of the object’s surrounding area. Parts of the “flaming/spark” details may be striations due to lens flare. According to astronomer and image processor, the camera position was steady during the exposure.

Lightning protection specialist Gugenbauer assumed a stroke of upward lightning as an explanation. His hypothesis is consistent, but fits neither the



Figure 5: Computer-enhanced flaring process, surrounding area and “sparks” of the possible kugelblitz, showing “multiple halo” and “turbulence signs”, produced by Peter Marx, UCLA.

observational data nor other case details. An observer would not describe a nearby stroke as a ball falling down for seconds. A logical foot-point for an upward discharge would be the local power-line pole. Why was it not illuminated and captured on the ball lightning photos pointing at 25° elevation (Grappeskogel) – now pointing at a horizon object (in order to be the foot-point the pole would have to be in the centre of the lightning photograph)? A ground stroke also would have resulted in a black-out and traces at the pole which were not observed.

Several questions remain after these analytical steps: Why did no terrestrial details at all show up on the kugelblitz frame? What could be the physical nature of the faint luminous track and the “sparks”? Is it possible to produce such an image by trick photography? Further interdisciplinary scientific study of the Sankt Gallenkirch photograph will yield more interesting results. The *J. Meteorology* readers are invited to form their own hypotheses about this case and to forward them for empirical tests.

SEVENTEEN MORE KUGELBLITZ CASES

When the photo-analysis was finished, the case details were released to the Austrian press. A story with colour photograph was carried by the local *Vorarlberger Nachrichten* on July 25, 1991, and another appeared in the newspaper *Kurier* all over Austria the next day. The photograph was talk of the day in the alpine valley – wherever he went, Burger got comments on it. However, calls for reports by the press and by two touristic newsletters yielded nothing.

Within the following weeks, Werner Burger was told of about 30 reports or report traces. People did not write, but they spoke. 22 of the reports could not be identified as ordinary lightning effects. 20 of them had happened in Vorarlberg, 17 within a radius of seven kilometres around the centre of Sankt Gallenkirch. All events were personally investigated by the author during two field trips to the area in 1991. As new reports are still forthcoming, only preliminary statistics are given here: Eleven objects were seen near the ground, ten lasted for two or three seconds (stopwatch estimates), nine had a reddish colour. Four objects allegedly exploded and/or caused damage.

The “Montafon cluster” (as we named it) offered a unique chance to speak to residents (nine are farmers or herdsman) who did not respond to the call for reports because kugelblitz was something “common”, not even especially exciting, for them. For our photographic case examination it is of interest that since 1933, and especially in the sixties and seventies (five cases each), ball lightning was observed frequently at Sankt Gallenkirch, Vorarlberg.

Acknowledgements: The author expresses his thanks for the friendly help of mayor Fritz Rudigier, the Burger family, other people of Sankt Gallenkirch, of the four expert witnesses – Zdenek Cepelcha, Claus Feuerstein, Alfred Gugenbauer, Peter Marx – as well as of Stanley Singer, Otto Svabik, Günter Kebeck and Kurt Schwarzenbacher.

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THE RAINFALL RECORD OF THE SAN FERNANDO OBSERVATORY, CADIZ: 1805-1990

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Abstract: The south-west corner of Spain is one of particular interest. Backed by high mountains and exposed to the Atlantic weather systems it enjoys its own regional climate. This paper summarises the rainfall observations over nearly two centuries from the Cadiz area.

The Royal Observatory of San Fernando, which is attached to the nearby important Spanish naval base, has a long and fascinating history which dates back to its foundations in 1753 (Wheeler, 1992). Although its functions principally as an astronomical observatory, the daily duties include the taking of meteorological observations. Fortunately, a series of directors and observers have ensured that an annual record of weather readings has been published since 1870 with an additional volume appearing in 1899 summarising the work from 1805, the year when specifically meteorological studies (where temperature and air pressure readings were required), were first taken (Pujazón, 1899).

The published volumes vary in the degree of detail they contain. Until 1969 they included vast accumulations of daily and, indeed, hourly data. Since that time a more concise presentation has been adopted. This first of a two part series examines the rainfall record, the secondary part will look at the temperature data, but other variables were also included of which wind speed

and direction, air pressure, sunshine, relative humidity and evaporation are the most important. Several of these variables have not, however, continued in the record in more recent years.

The station is located in the grounds of the Observatory in San Fernando some 7 km from the city of Cádiz (from where the observatory had been moved in 1797) at 36° 28' N and 6° 12' W at an altitude of 28.5m above sea level. Cádiz province is Spain's most south-westerly and has a long Atlantic seaboard that stretches from Gibraltar to the mouth of the Guadalquivir river (Figure 1). The inland areas are mountainous and rise to over 1000m ASL. Beyond the provincial boundary to the east the appropriately-named Sierra Nevada (snowy mountains) attain even greater heights and exceed 2500m in many places.

RAINFALL MEASUREMENTS

The rainfall record, which begins in 1805 and continues to the present day, is one of Europe's longest. There are, however, some gaps in the sequence particularly in the early years though it is not certain whether this is because of failure to take the readings in the first place or because of their subsequent loss during the less than tranquil history of nineteenth and twentieth century Spain. Table 1 summarises the availability of monthly totals between 1805 and 1988.

From 1870 until 1988, when the station was automated, rainfall was measured using a form of daily gauge. The gauge was sited in the grounds of the main observatory approximately 30m south-west of the main building. The first unambiguous description of the instrument appears in the 1870 report where it is described as a funnel of 0.34m diameter connected directly to a measuring cylinder. The run of the funnel stood just over 1m above the the

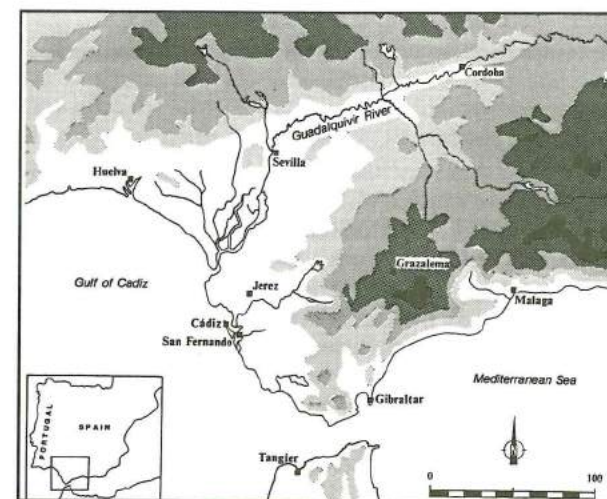


Figure 1: Map showing the location of Cádiz and San Fernando in southern Spain. Relief shading is given by zones 0-100m, 100-200m, 200-500m, 500-1000m and over 1000m.

TABLE 1: Record of availability of monthly data from the San Fernando observatory 1805 to present. The gaps may be a result of loss of data but, as they often coincide with periods of war, the observations may not have been made.

Nature of record	Years covered
No monthly record	1810-1811, 1814-1816, 1833, 1836, 1986
Partial record (some months missing)	1806-1809, 1812, 1824-1825, 1835, 1934
Monthly record complete	1805, 1813, 1817-1823, 1826-1832, 1834, 1838-1933, 1935-1985, 1987-

ground. Measurements were originally made in inches and then converted into millimetres. This practice may be explained by the fact that, at that time, most of the instruments were purchased in Britain, the observatory then having no means of manufacturing its own meteorological items. By 1900 a newer but otherwise similar system had been installed and remained in service until the adoption of the automated station. Of the instrumentation before 1870 almost nothing is known but it appears probable that something close to the system described above may well have been in use. Future searches of the extensive archives may reveal more on this point.

Such data as survive from the period 1805 to 1836 indicates a possibly intermittent record. Monthly, but not daily, totals are listed. From 1868 onwards the civil day was used (midnight to midnight) but between 1836 and 1868 it appears that, on some occasions, a noon-to-noon day was preferred. In some cases it is impossible to determine which 'day' has been used. For many years readings were taken every four hours and added to give daily totals. As the twentieth century passed however a system of single daily readings was adopted. Unfortunately, in view of the occasional very high daily totals, no autographic gauge was used until the adoption of the automatic system in the late 1980's.

THE RAINFALL CLIMATOLOGY OF CÁDIZ

Whereas some Spanish researchers have published items (Martín Vide, 1991) few authoritative texts in English discuss the climatology of this part of Spain. The best is by the Meteorological Office (1978). Nevertheless it was as early as 1851 that the inveterate Iberian traveller Richard Ford observed that Spain could be divided into four climatic zones the fourth of which, his so-called *Baetican* region, embraced the Cádiz area. His description, simple though it might be, remains informatively true today "... the winters are short and temperate, and consist rather in rain than in cold, for in the sunny valleys ice is scarcely known except for eating; the springs and autumns delightful beyond all conception" (Ford, 1851).

At the latitude of Cádiz the influence of the semi-permanent Icelandic low and its associated weather systems is less than over more northerly regions but is far from non-existent particularly in the winter season. Secondary depressions formed from primary systems to the north occur commonly in

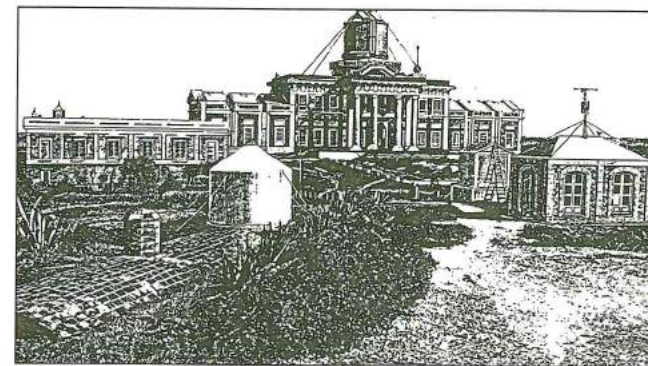


Figure 2: The San Fernando Observatory as it would have appeared in the middle of the nineteenth century.

winter when they may pass through the Strait of Gibraltar or along the low-lying ground of the Guadalquivir valley (Capel Molina, 1981). The Atlantic aspect of the Cádiz area makes it particularly subject to such systems, more so indeed than most other areas of southern Spain the majority of which lie to the east and enjoy varying degrees of protection from the incomplete barrier of land to north and south of the Strait of Gibraltar and from the Sierra Nevada. The frontal rainfall is accentuated by orographic influences in the more mountainous districts. But some of the most spectacular rainfalls occur in autumn as a result of cut-off lows that form beneath cold pools under a regime of low-index westerlies. Such features may occur at any time but have a marked preference for October when sea temperatures retain much of their summer heat and average sea surface temperatures may reach 20°C. The early invasion of cold polar air aloft may create violent instability. On rare occasions such systems may even temporarily replace the semi-permanent Azores anticyclone. During the summer, however, the strength of the anticyclone exercises a profound grip on the rainfall regime which is only occasionally broken by southerly-tracking frontal systems and troughs.

Precipitation is almost exclusively in the form of rain and hail, particularly in this coastal area, but snow is not unknown though it is exceedingly rare and falls less than once in twenty years. However on the high ground to the east snow is a regular part of the winter precipitation regime. Not without some justification Martín Vide (1991) has suggested that the Gulf of Cádiz be considered as "centre of action" in the way that the Icelandic low-pressure and Azores high-pressure areas act as foci of important climatological activities. Although obscured by the inclusion of summer 'thermal' lows over the Iberian mainland, figure 3.7 in Met. Office (1978) suggests that during spring and autumn this area does, by the standards of its latitude, witness unusual degrees of cyclonic activity.

The Cádiz area and its immediate hinterland are of low and undulating topography. The orographic factor in rainfall is probably limited in the low-

lying coastal districts, though not further east where the western hills of the Penibaetic ranges rise abruptly from the Guadalquivir lowlands. Rainfall is principally frontal in origin with a convective component especially in spring and autumn. Capel Molina (1981) describes the region as Oceanic-Mediterranean. The Atlantic influence is pervasive and the local annual totals are high for their latitude and may also be accompanied in winter by long spells of overcast weather more familiar to those of us from more northerly locations. Rainfall varies between 500 and 700mm annually over the lowlands but further inland totals increase spectacularly with altitude. Grazelama (at 823m ASL to the north-west of Ronda and only 80km east of Cádiz represents the extreme case with an annual mean precipitation of 2223mm.

STATISTICAL REVIEW OF RAINFALL IN CÁDIZ

The long term monthly and annual means are listed in Table 2 which also shows the respective degrees of variation in terms of the absolute ranges and, more informatively, the standard deviations. The seasonality of the regime is perhaps its most striking feature, followed by the annual total which reflects a moist Atlantic influence that dominates all but the mid-summer months.

Several further points can be noted. The seasonality is self-evident but each month's rainfall is also highly variable from year-to-year. All months, save December, have recorded at least one occasion when no rain has fallen while, at the other extreme, only May, July and August have maxima that do not exceed 200mm. As a consequence of this variability the standard deviations of the monthly data are large compared with the means. Even the annual totals do not altogether disguise this characteristic. The mean of 606.5mm is matched by a standard deviation 193.6mm. The wettest year was 1855 (1262.5mm) while the driest was 1828 (286.7 mm). The distribution of the monthly means also shows a degree of positive 'skew' with the arithmetic means exceeding the median value (Figure 3). As a measure of 'central tendency' the latter might, therefore, be preferred though neither adequately convey the character of the monthly rainfalls.

Data also exist for rain days, which are here taken as days with 0.1mm or more of rainfall. The first year of such data is 1837 from when it has continued to the present. However, from 1870 onwards the recorded 'rain day' totals included days with a 'trace'. Sufficient information exists from between 1870 and 1900 and from 1940 to the present to allow the 'trace days' to be subtracted from the recorded total. But for the period 1900 to 1940 a derived correction had to be applied based on the monthly average of 'trace days' between 1870 and 1900. The following results are based on these corrected values. It can be readily appreciated that 'rain days' is a more conservative variable than rainfall totals. The mean annual total is 81.4 but has a standard deviation of only 20.4. The correlation coefficient between annual rainfall and rain days is significant at the 0.05 level with $r = +0.470$ but is, perhaps, less than might have been anticipated and leads to a coefficient of explanation of only 0.221. Expressed otherwise, the variation in rain days 'explains' only 22.1% of the variation in the annual rainfall.

TABLE 2: Statistical summary of rainfall at San Fernando (Cádiz). The rainfalls are all in mm and based on the observational period 1805-1988 (see also table 1). Rain days data are for the period 1837-1988.

month	mean	median	maximum	minimum	standard deviation
January	81.3	63.2	304.1	0.0	62.84
February	67.8	62.7	291.5	0.0	52.16
March	70.1	61.9	236.0	0.0	49.71
April	50.7	38.2	270.1	0.0	41.25
May	35.7	26.5	234.2	0.0	35.32
June	12.8	5.4	206.9	0.0	21.29
July	1.2	0.0	34.3	0.0	4.31
August	2.8	0.0	68.2	0.0	8.65
September	23.0	11.3	245.3	0.0	35.55
October	72.6	55.0	307.3	0.0	62.03
November	97.5	83.5	470.5	0.0	75.92
December	9.16	78.2	377.7	1.2	69.53
year	606.5	573.8	1262.5	286.7	193.60
rain days	81.4	83.0	136	34	20.43

In part, at least, the relatively weak association between rainfall and rain days is accounted for by the frequency with which a single day's total may contribute a substantial amount to the annual figure. Here again we are fortunate in having at our disposal the highest daily totals for each month between 1868 and 1988 from which the 'annual series' can be abstracted. The first point to be made is that the annual series for Cádiz makes far less impressive reading than the corresponding figures for, for example, Barcelona (Wheeler, 1988). This difference again reflects the Atlantic influence that holds sway over Cádiz. The Atlantic waters ensure that Cádiz and adjacent districts receive annual rainfall totals that are welcomingly high for the latitude. But those same waters are here a relatively cool, southwards returning branch of what was once the North Atlantic Current. The temperatures attained in the enclosed waters of the Western Mediterranean basin at the conclusion of the summer are not to be encountered in these open oceanic settings. As a result convection and instability are rarely so marked as in the Mediterranean and the

TABLE 3: Estimated annual maximum daily totals (in mm) on the Gumbel (EV1) distribution for San Fernando and areas in eastern Spain. (source: *Pluges i Inundacions a la Mediterrània* by J. Martín Vide (1985), Kestres, Barcelona).

station	return period (years)					
	10	15	20	30	50	100
San Fernando (Cádiz)	90.3	99.0	105.2	113.7	124.4	138.8
Gerona	179.0	199.2	213.5	233.2	258.1	291.0
Barcelona	105.1	114.7	121.5	130.8	142.7	158.2
Valencia	159.9	180.3	194.7	214.5	239.7	272.8
Málaga	121.9	135.2	144.7	157.7	174.2	195.9

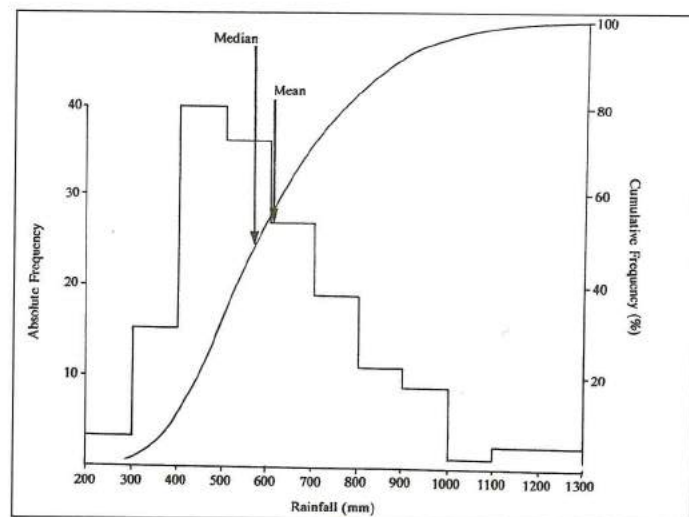


Figure 3: Histogram and cumulative frequency curve of annual rainfall at San Fernando over the period 1805 to 1988. The statistical distribution shows a positive skew typical of much hydrological and meteorological data whereby the arithmetic mean is displaced towards the right (high magnitude) side of the median.

annual series reflects this overriding geographical control. The greatest daily total on record for Cádiz is 140.5mm (on 28th October 1960). In contrast, there is scarcely a location along the Mediterranean coast of Spain that has not had at least one daily total in excess of 200mm in the last 50 years and in some instances totals of over 300mm are on record. Almost without exception such events are the result of autumn instability of the type described by Wheeler (1991).

The mean of the Cádiz annual series is 53.22mm and, on average, the wettest day of the year contributes an impressive 9.01% to the annual total though that proportion varies enormously between 21.0% (in 1906) and 4.2% (in 1855). Based on the annual series Table 3 was constructed. However, a word of warning is necessary. The annual series is determined, as convention dictates, by reference to the single highest daily total each year. There are several cases where the highest daily total in any one year, if low, falls short of the second, or even the third, highest totals in some other years. Yet the latter values are excluded from the series. Whilst this ensures that the series consists of 'independent' events it simultaneously excludes some significant isolated occurrences. Thus the underlying probability of rainfalls of certain depths may be slightly higher than is interpreted from the analysis of annual series *sensu stricto*.

The seasonal timing of the annual event in Cádiz shows a marked autumnal preference but, as Figure 4 shows, the incidence of such events in other months is far from unknown. Only June and July have failed to produce the wettest day

of at least one year. Even May (43.5mm on 6th May 1971) and August (51.8 on 8th August 1854 and 50.3mm on 29th August 1944) can claim that distinction.

The autumn concentration of high rainfall events results from the same combination of factors that explain the Mediterranean storms, i.e. early outbreaks of polar air over a sea at its late summer maximum temperature. When combined with mid-tropospheric cut-off lows, that can be remarkably persistent at this time of year, the Cádiz region can experience prolonged spells of stormy and wet weather at almost any time during the winter season. The Iberian traveller, Henry Swinburne, fell foul of such weather in 1776 when he visited Cádiz. Having arrived there on 14th January his diary entry for 30th reads "... I scarce hope to see a fair day again, for we have had nothing but rain since our arrival ..." (Swinburne, 1779). Just thirty years later Admiral Cuthbert Collinwood was to have even greater cause to lament the inclemency of such weather as he tried to marshal the shattered English fleet through a week-long storm following the Battle of Trafalgar (Wheeler, 1987). Cut-off lows which persist in the Gulf of Cádiz tend to promote strong south-westerly winds known locally as *vendavales*, but any outbreak of westerly or north-westerly air, especially if accompanied by cold front squalls, is likely to promote rain on exposed coastal sites though their vigour diminishes rapidly inland. In winter even such southerly locations as Cádiz will not escape the regular attentions of such weather. Only in summer, when the Azores sub-tropical high intensifies and moves northwards, is dry weather more certain. At this season rainfall can indeed be a very rare phenomenon. July and August are the most drought-prone months, though even they can produce the occasional high total. August 1944 yielded 68.2mm of rain and in 1918 July 34.3mm. These exceptions notwithstanding, July has passed on 149 occasions since 1805 without rain. The corresponding figures for June and August are 99 and 133 respectively.

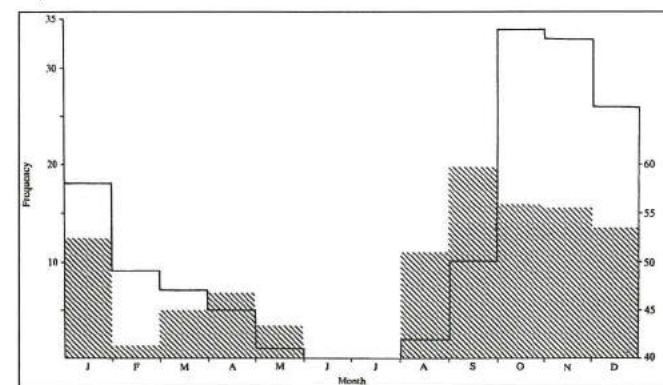


Figure 4: Histogram showing the monthly distribution of the wettest day in each year of record (1837-1988). The shaded histogram shows the average rainfall (in mm) for each month's sample of wettest days.

CONCLUSION

The climatology of the Cádiz area represents another facet of the veritable kaleidoscope of Iberian climates. The interaction of sea, land and air here produce a rainfall regime that is wet given the latitude and marked by variations both within and between the years. This later feature suggests a climate that is sensitive to the delicate equilibrium of climatic forces and, in particular, to the activity and location of the Azores semi-permanent 'high', any change in which may greatly modify the incidence of rainfall. In the light of current predictions about our global climate scientists may do worse than to look to such areas for signs of change to complement the wealth of information from the European mid-latitudes.

Acknowledgements. The author gratefully acknowledges the financial assistance of the Royal Meteorological Society and of the British Council in the preparation of this paper.

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CLIMATE AND POPULATION IN TEMPERATE AND COLD AREAS

By R. A. BECK

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Abstract: It is shown that the population density of various islands with temperate or cold climates is an exponential function of the summer temperature of those islands. Also, the population of the largest towns in certain temperate or cold climates is shown to be related to the summer temperatures. The implications of these relationships are discussed.

INTRODUCTION

A recent paper (Beck 1992) showed that the population density of the main island and island groups in the British Isles can be expressed as an exponential function of their values of the optimum summer index as defined by Davis (1968), the islands with warmer, drier, sunnier summers having the higher values of the index and being the more densely populated.

This paper examines several other cases in which there is a clear relationship between summer climate and population.

CLIMATE AND POPULATION DENSITY OF ISLANDS

Let us first examine the relation between climate and population density for certain islands and island groups in the southern hemisphere and in Canada which have temperate or cold climates. Davis's optimum summer index was introduced to describe summers in the United Kingdom and may not be applicable to the southern hemisphere and Canada. The summer climate will therefore be described by:

the mean January temperature for the southern hemisphere islands

the mean July temperature for the Canadian islands.

The logarithm to the base 'e' (natural logarithm) of the population density, p persons per square kilometre, is used, and temperature values generally relate to the more densely populated parts of an island (group) if there is a wide temperature range within it.

Figures 1(a) and 1(b) are the resulting plots with the least squares regression lines included. In both cases the population density is close to an exponential function of the mean summer temperature. Figures 2(a) and 2(b) are the corresponding plots against winter temperature, but for which there is less correlation.

The following table summarizes the correlation coefficients:

Islands	Parameter	Correlation coefficient
British Isles	optimum summer index	0.969
	mean daily max. temperature in June, July, August (summer)	0.914
	mean temperature in December, January, February (winter)	0.455
Southern hemisphere (New Zealand Tasmania etc.)	mean temperature in January (summer)	0.952
	mean temperature in July (winter)	0.797
Canadian	mean temperature in July (summer)	0.968
	mean temperature in January (winter)	-0.464

CLIMATE AND POPULATION OF TOWNS

The optimum summer climate index, I_0 (Davis 1968), expresses the quality of

summers at a given site in the United Kingdom. It takes into account the mean daily maximum temperature, the mean daily duration of bright sunshine and the total rainfall during June, July and August. Values of I_0 at sea level range from about 500 to 800 (Davis 1968).

Consider a plot of the logarithm to the base e of the population of towns in the UK against the value of I_0 pertaining to their summer climate as in Figure 3 where population data from the Office of Population Censuses and Surveys (1981) and Whitaker's Almanac (1986) are used. Values of I_0 are taken from Davis (1968) or calculated from data in Meteorological Office (1972). Where no data were given specifically for a given town, data for a nearby site were used. The term 'town' as used here includes both towns and cities.

The towns included in Figure 3 are as follows:

- (1) the largest town in each of the counties listed in Office of Population Censuses and Surveys (1981), and London
- (2) the four largest towns in Scotland
- (3) the two largest towns in Northern Ireland
- (4) all large towns identified by map inspection which have low values of I_0 because of their high altitude (e.g. Buxton) or very northerly location (e.g. Lerwick). A special symbol is used for these towns.

The above sets ensure a good geographical coverage and in particular set (4) helps to fill in the low I_0 region.

Figure 3 shows that the population of the largest towns increases with the value of I_0 . Thus it shows:

there are no towns of more than 10,000 people where $I_0 < 650$

there are no towns of more than 30,000 people where $I_0 < 670$; etc.

The area of the population domain in which the data points fall is bounded by a smooth curve or envelope to the upper left of which there are no towns. The envelope is shown by a broken curve where there are few towns.

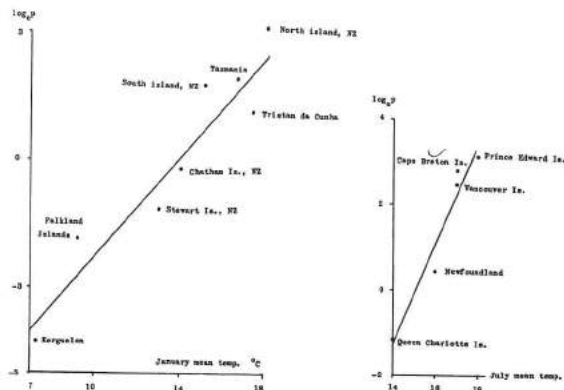


Figure 1: (a) Population, p , and summer temperature (southern hemisphere islands). NZ denotes New Zealand. (b) Population, p , and summer temperature (Canadian islands).

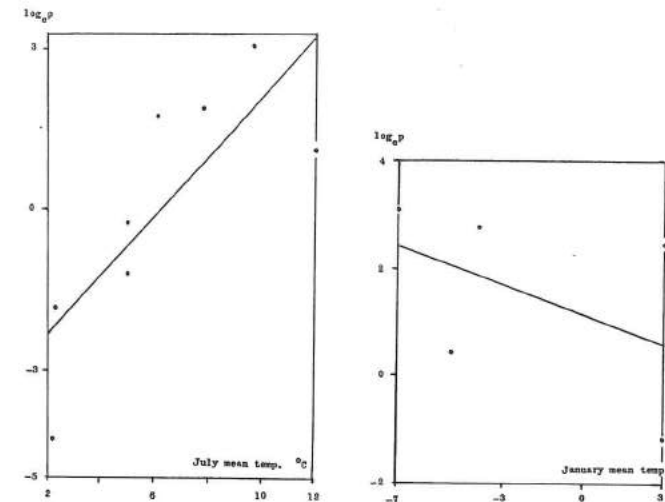


Figure 2: (a) Population, p , and winter temperature (southern hemisphere islands). (b) Population, p , and winter temperature (Canadian islands).

Figure 3 suggests that climate is at least a factor in limiting the size of towns in the UK. In particular Buxton, Bacup and Darwen are towns with low values of I_0 due to high altitude and they are close to large lowland cities (Derby, Nottingham, Manchester).

Figure 4(a) shows the population of all towns of over 100,000 people in New Zealand and Tasmania plotted against their mean January temperature (in these islands January is often the warmest month). Similarly Figure 4(b) is for towns of over 150,000 people in Scandinavia. In both cases the size of the largest town is a monotonically-increasing function of summer warmth.

In Figure 3 particularly there is a crowding of data points on the right showing a numerical weighting of large towns to the areas with warmer summers.

CONCLUSIONS

Given several cases of close correlation between population and summer climate, as summarized in the above table and diagrams, it seems that, barring enormous coincidence, summer climate exerts a strong control over the degree of development of temperate or cold areas. This may be partly, and in some cases indirectly and historically, due to the effect of summer climate on agricultural productivity or, in the case of towns, to the agricultural productivity of their environs. (Most of the places considered are too cold in winter for much agricultural activity). Although, in modern advanced societies, man may feel somewhat independent of climatic factors, they exert strong controls.

It is worth considering the implications of the climatic correlations. It appears that population in at least some temperate or cold regions adopts a natural

distribution describable mathematically. In England this manifests itself in 'the drift to the south'; the centre of gravity of the English population has moved southwards since the early part of this century as the industrial centres of the north declined. As the distorting effects of the industrial revolution weaken, population reverts towards a distribution heavily weighted to the south which has relatively warm summers.

Regional policies aimed at vitalizing the areas of a country with very cool summers may be misguided because they oppose strong natural trends and may, at some expense, encourage people to live and work where they do not enjoy the annual psychological boost of a good summer with its attendant comforts, opportunities for outdoor activity and savings on fuel for space heating. (In many of the cases considered, high summer temperatures, long periods of summer sun and low summer rainfall largely go together).

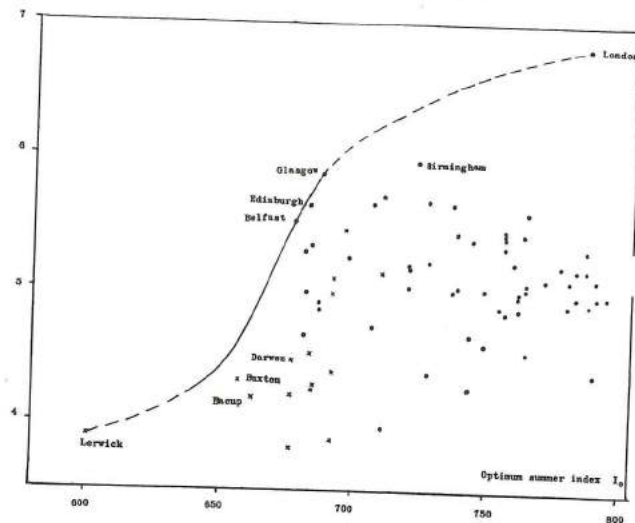


Figure 3: Population, p , of towns in the UK and their summer index values (towns chosen for their low index numbers are marked x).

There are lessons too for town planners who should interpret the curves of Figures 3-4 in terms of the maximum desirable size of towns for given summer conditions. In a small town, reasonable closeness to the countryside may offset the climatic disadvantages, but large towns with poor summer climate pose special problems. Efforts to improve existing cities, such as Glasgow and Belfast, on the upper left edge of the envelope of Figure 3 could therefore be particularly beneficial.

The lessons for temperate and cold countries can be summarized thus:

- (1) People tend to choose where they want to live and their choice is somehow, perhaps indirectly and subconsciously, influenced by summer climate.
- (2) Incentives to persuade people to live in areas which happen to have the

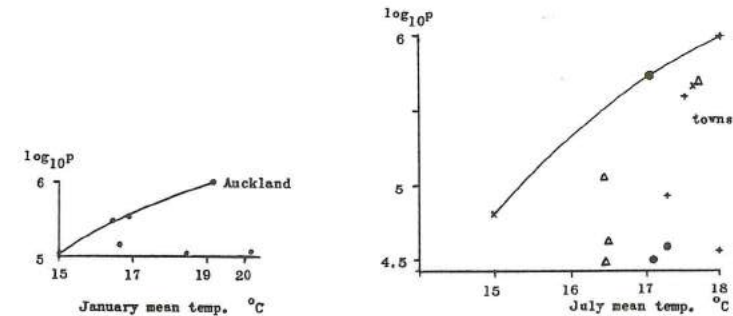


Figure 4: (a) Population, p , of towns in New Zealand and Tasmania and their summer temperatures. (b) Population, p , of towns in Scandinavia and their summer temperatures.

coolest, wettest, dullst summers could perhaps be better directed elsewhere.

- (3) Efforts to improve existing large towns in areas with cool, wet, dull summers could be very useful.

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LETTERS TO THE EDITOR

ATMOSPHERIC RYDBERG'S MATTER AS A POSSIBLE MODEL FOR BALL LIGHTNING

I would like to draw attention to the possibility of an explanation for ball lightning by using recent results of the investigation of matter in a strongly excited state. We use the conception of 'Rydberg's Matter' for this purpose. Rydberg's Matter is the condensed state of the excited electrons in the high quantum levels of atoms or molecules when their valence electrons are collectivized. The formation of Rydberg's Matter is like the formation of the alkali metals. When the atoms are excited their effective sizes quickly increase. The valence electrons spend almost all their time far from their ions. Therefore when the density of highly excited atoms is greater than α_n/a^3n^6 , a phase transition to the condensed excited state occurs. Here a is the Bohr radius, n is the quantum level number and α_n is slowly dependent on the n number. Rydberg's Matter is a metastable long-lived state. In the condensed excited phase the valence electrons are collectivized, so the binding energy of atoms is of the same order as the kinetic energy of the valence electrons in the initial excited atoms. For the 'atmospheric Rydberg's Matter', when the density of the collectivized electrons is about 10^{17}cm^{-3} , the binding energy is approximately 10^3K , the surface tension is about 0.1 erg/cm^2 , the electrical conductivity about $10\Omega^{-1}\text{cm}^{-1}$, and the stored energy about 1J/cm^3 .

Atmospheric Rydberg's Matter is usually transparent because of low electron density, but it may be visible due to the recombination radiation. Most of the parameters of atmospheric Rydberg's Matter coincide numerically with ball-lightning statistical parameters. That is why atmospheric Rydberg's Matter may be considered as a possible model for ball-lightning.

We have published several works devoted to the theory of the condensed excited state:

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I would very much appreciate receiving any information on this subject.

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Sergiev Posad, 141335 Russia.

MICHAEL I. OJOVAN

THE SHETLAND HURRICANE OF 1 JANUARY, 1992

Very deep and intense depressions often move north-east close to Iceland near the time of the lowest sun and the central pressure sometimes falls to about 930mb at Spitzbergen. As these lows move north-east, they give the Faeroes a hard battering. However, it was Shetland's turn in the winter of 1991/92, for two very intense depressions moved east-north-east directly over Faeroes and central pressure fell to the 930's mb.

The first low was on 19 December 1991 and produced a violent westerly storm in Shetland, giving the islands a hard battering, ready, unfortunately, for the New Year's Day 1992 hurricane, which caused widespread structural damage, qualifying the islands for government aid.

Gusts exceeding 100 mph were recorded at Sumburgh. Winds were much stronger than this in very exposed places, and strongest of all in North Shetland nearest the centre of the low. Consequently, damage was worst in North Shetland. The wind was particularly violent in hail showers. Two people were killed when the hut in which they were sheltering was blown over cliffs into the sea. The domes of the early-warning radar system on Saxa Vord Hill (935 ft) were ripped off leaving the radar exposed to the elements. Many houses were damaged and some, including two hotels, were demolished. Caravans and greenhouses were destroyed. Some smaller boats drawn up on land were lifted bodily and destroyed.

This is thought to be the worst hurricane in Shetland since the south-east hurricane of 16 February 1900. A south-west hurricane on 27 January 1961 gave Lerwick a 109 mph gust, but much less damage was done than in this most recent hurricane.

Whalsay, Shetland.

S. G. IRVINE

PERSISTENT WINTER HIGH PRESSURE IN THE BRITISH ISLES

I wonder if anyone can find in their records for the British Isles a period of 82 consecutive days when their MSL average pressure has exceeded 1028.6mb. It has been this figure here in Cardiff from 19/11/91 to 8/2/92. I have chosen the date of 19/11/91 because the pressure has been above 1000mb since then, based on daily readings at 0900 hours. Since 19/11/91 the lowest pressure has been 1001mb on 9/1/92 when the pressure was rising quickly. Whether the pressure was above or

below 1000mb on this date depended on whether you read it at 0830, 0845 or 0900 hours. Cardiff's average MSL pressure is only 1013mb for November, 1011mb for December, 1015mb for January and 1013 for February, whilst for the year as a whole it is 1014.2mb. The highest average monthly pressure here in Cardiff during the last three years has been 1031.9 in January 1992, 1029.3 in December 1991, 1027.2 in March 1990 and 1026.5 in January 1989 and May 1991. So when will we have a long spell of low pressure to balance out this prolonged spell of high pressure? Furthermore what is the highest winter pressure recorded for the winter months of December, January and February in the British Isles?

I have also noticed that the very high pressure in the months of January 1964, February 1959 and December 1975 were followed by some prolonged dry months, although the autumns that followed these spring and summer months had rainfall near average or above. I wonder if the present persistent high pressure pattern is similar in any way to these years of 1959, 1964, and 1975/1976 – perhaps someone would like to answer this question for our readers.

With all this high pressure this winter there has been low rainfall in South Wales as one would expect. For example at Cardiff (Rhoose) from 21 November 1991 to 7 February 1992 (79 days) there has been 86.2 mm which is only 9% of the annual average of 929 mm, with 20 rain days and 11 wet days in these 79 days, whilst 40.9 mm of this 86.2 mm has fallen on only three days. Despite this low rainfall, sunshine has been low too, with only 86.0 hours in these 79 days at Cardiff (Rhoose).

This winter's high pressure in January has produced temperatures above average on the high hills in South Wales, while there have been below average temperatures in the coastal regions of the Bristol Channel. For example, on 31 January the day maximum in the foggy coastal regions of the Bristol Channel only reached 0.6° at Cardiff (Rhoose), 1.5° at Cardiff (Llandaff), 1.0° at Minehead (Somerset) and 2.4° at Penmaen on the Gower, compared with a maximum of 11.1° on the sunnier high ground of South Wales at Cwmbargoed, near Merthyr Tydfil at an altitude of 1220ft AMSL. In January this year Cwmbargoed had a record number of 17 sunny days and a record number of 20 days of no measurable rainfall, compared with 17 days of no sunshine and only seven days with more than 1.0 hour of sunshine at Cardiff (Rhoose). The records at Cwmbargoed go back to 1967.

The rainfall needed at Cardiff (Rhoose) during the last 22 days of this winter to equal the driest winter in 1964 (records go back to 1955) is 10.3mm, 57.8mm to equal the next driest winter in 1963, and 67.9 mm the next driest winter in 1976. For sunshine at Cardiff (Rhoose), 32.1 hours are needed to equal the dullest winter of 1964, 33.5 hours the next dullest in 1957, and 43.8 hours the next dullest in 1976. Also I noticed that the rainfall for Cardiff (Rhoose) of 711 mm in 1964 was the second driest year there from 1955 to 1991, and that across the Welsh border in Gloucester, 1964 was the driest year from 1950 to 1979 with only 441 mm.

So what has the rest of 1992 in store for us in regard to pressure and rainfall?

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JOHN TRENCHARD

TORRO THUNDERSTORM REPORT: July 1991

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July was a mostly unsettled month and with winds frequently in the south temperatures were often on the warm side. All regions of the U.K. and Ireland had above average thunder-day totals with only a few observers failing to hear any thunder at all. Generally, southern and eastern counties were most thundery with three or four days quite widely and with five in some places, but four or five were also reported locally as far north at Lancashire and Cleveland.

With a trough of low pressure lying across central Britain heavy thundery showers and thunderstorms developed over Northern Ireland and adjacent parts

Thunder-days in July 1991 were as follows: (averages refer to the period 1961-90)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Tot	Ave	
England	X	X	X	X	X	X	X	X			X	X			X		X							X	X	X				X	X	X	18	15
Wales		X		X	X	X	X	X																X						X	X		8	7
Scotland	X	X						X	X			X	X								X										X		9	8
Ireland	X	X	X	X		X	X								X										X					X	X		10	7
Total	X	X	X	X	X	X	X	X			X	X	X		X	X		X		X				X	X	X				X	X	X	21	17
Netherlands	X	X	X	X		X	X	X	X			X	X	X			X							X	X					X			15	17
Belgium	X	X	X			X	X	X	X			X	X											X	X					X	X		13	

of the Irish Republic, southern Scotland and northern England on 1st. In Ireland the border town of Castleblayney in Co. Monaghan was severely flooded during a torrential thunderstorm with many properties flooded, some to a depth of two metres. On 2nd, with the trough now lying across southern Britain the thundery area moved a little further south to affect parts of Ireland, the Greater Manchester area and north Wales, with very isolated activity in north-east England and Sussex. In Banbridge, Co. Down an 11-year-old girl was badly burned when lightning struck the swing she was using and in Cork hailstones up to 2.5cm in diameter fell during a severe thunderstorm. Easterly winds covered the country on 3rd and an area of heavy rain that moved north-west across the country overnight and during the morning produced a clap or two of thunder over Lancashire, southern Ireland and possibly over the mountains of south Wales. The 4th was a hot and sunny day but west Cornwall was quite cloudy with thunderstorms by late morning and scattered thundery outbreaks were reported from south-west Eire and Anglesey in the evening.

The Scilly Isles were subjected to prolonged thundery activity on 5th accompanied by very heavy rain that totalled 107.2mm for the 24-hours beginning 0900 GMT on 5th. After a sunny day southern areas of Britain turned more cloudy in the evening and a band of thunderstorms crossed the Channel from France and made steady northward progress across southern counties of England and Wales by midnight. Although heavy rain, squally winds and some hail accompanied these storms they will best be remembered for the intensity and frequency of the lightning. Many observers in central-southern England reported almost continuous lightning for prolonged spells.

The storms made steady progress northwards during the early hours of 6th but although of a severe nature the frequency of the lightning decreased markedly. Incidents of lightning damage were far too numerous to list in any detail but right across southern England and the midlands many buildings were damaged and power supplies disrupted. The counties of Dorset and Hampshire were particularly badly affected and a number of houses were struck by lightning in West Midland. The storm area reached northern England later in the night and during the morning and again property was struck by lightning. However, the most serious incident occurred at Leigh in Greater Manchester where a 26-year-old man was killed by lightning whilst fishing. His boy companion was unhurt. Later on 6th and through the early hours of 7th a good deal of lightning was observed over the southern North Sea and near continent

by observers in south-east England. Northern and eastern areas of Britain were hit by further outbreaks of thunderstorms during late afternoon and evening of 7th. In the Nottingham area the storms were described as the worst for a number of years and a funnel cloud was observed reaching almost to the ground. At Northallerton in North Yorkshire lightning blew a garden shed apart and the intense heat welded tools and garden chairs together. As the upper trough moved north across Scotland there was thundery activity over Northern Ireland and Scotland on 8th with only scattered thunderstorms further south.

After a couple of thunder-free days thunderstorms developed in the medium-level cloud of a cold front as it moved eastwards across the British Isles on 11th with much of the activity over the more northern and eastern counties of England and Scotland and storms over the Northern Isles of Scotland continued into the early hours of 12th. In an isolated storm over Somerset a 20-year-old painter and decorator fell seven metres from a metal ladder when lightning rent apart a nearby oak tree at Stawley, near Wellington. She received a serious knee injury that required 20 stitches. On 13th a number of thunderstorms developed over Nottinghamshire and Lincolnshire in the afternoon and over Kent and East Sussex in the evening, close to a ripple moving eastwards along a cold front lying across southern counties of England. During the passage of a particularly active cell that crossed Lincolnshire in the early evening a tornado caused some damage at Castle Bytham. Very scattered thunderstorms affected Northern Ireland and the Scottish Grampians on 15th and parts of East Anglia had some thunderstorms on 16th. In early hours of 18th thunder accompanied heavy rain in the Minehead area of Somerset and on 20th isolated thundery showers were reported over the mountains of Highland in Scotland.

Banks of thunderstorms moved eastwards across South Wales, the midlands and southern and eastern counties of England on 23rd, during the passage of two cold fronts across the country. Thunderstorms initially affected west Cornwall around dawn and during the course of the day thunderstorms progressed eastwards to reach East Anglia around mid-evening. The storms were generally not all that active except in some eastern areas in the evening where some intense activity was reported. Several houses were struck by lightning on Humberside, lightning also damaged property in east Kent and at Mannings Heath in West Sussex a petrol filling station was struck by lightning. A depression tracked south-eastwards across the British Isles on 24th and thunderstorms developed in places, particularly around its south-eastern quarter, affecting parts of eastern Ireland and the south-east of England in the morning and more widely over eastern England in the afternoon and evening. There were also thundery outbreaks in east Kent in the early hours of 25th. With a depression off Biscay a trough moved north from France late on 29th and thundery developments drifted north-westwards across south-western parts of England and Wales and southern Eire in the evening. Storms continued to affect the south and east of Ireland and parts of Dyfed in the early hours of 30th and as the trough continued to drift north heavy rain and local thunderstorms had reached a line from Merseyside to East Anglia by evening. During the Irish

storms an electrical engineer at Cork was injured as he worked on a 38 kv substation and ten cows were killed when lightning struck a tree on a Co. Cork farm. Four jackdaws were also killed in this incident. A few storms lingered over central England into the early hours of 31st and late in the day there were thunderstorms in Shetland as storms tracked north-westwards from Denmark.

TORRO THUNDERSTORM REPORT: August 1991

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August was a dry, sunny and warm month and thunderstorms only occurred during brief interruptions to the general anticyclonic theme, hence totals were significantly below the normal for this high summer month in all parts of the United Kingdom and Ireland. Many observers right across the country failed to hear any thunder but one day was reported most widely over south-eastern counties of England with two days locally in the Midlands and Humberside.

Thunderstorms that were affecting the Shetlands late on 31 July lingered into the early hours of the new month. Late in the morning of the 1st showers and scattered thunderstorms developed over East Anglia and during the course of the afternoon thunderstorms developed widely over the east Midlands, East Anglia and southwards to the North Downs of Surrey and Kent, dying out during the evening. Flooding occurred widely and there was considerable lightning damage. The most serious lightning incidents were reported at Sevenoaks, where a woman was killed as she sought shelter in the town centre, and at Brentwood, where a man was badly burned when lightning struck the tip of his golfing umbrella. At Lakenheath in Suffolk the local observer reported a "rather frightening" whistling noise at the time of an overhead lightning discharge. Many observers reported seeing lightning strikes to earth and this was confirmed by the numerous reports of damage to buildings throughout the affected area. In addition to torrential rain, hail accompanied the storms in Surrey with reports of golf-ball sized stones in places. On 3rd a cold front made steady progress across the British Isles and thunderstorms developed along the front over the Midlands and southern counties of northern England during the afternoon and evening. The storms were quite active in places and at Wolverhampton a dramatic squall-line was reported. After a cloudy day on 5th

Thunder-days in August 1991 were as follows: (averages refer to the period 1961-90)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Tot	Ave
England	X	X		X												X	X				X	X	X								X	9	14
Wales					X																	X	X								X	4	8
Scotland	X																X					X										3	8
Ireland																X					X	X	X									4	7
Total	X	X		X	X											X	X				X	X	X								X	10	17
Netherlands					X	X	X										X	X				X	X									7	15
Belgium	X					X	X										X					X	X									6	

with outbreaks of rain, further heavy rain spread north-east across Wales in the evening and thunder was heard to the east of Barmouth. A small cyclonic disturbance moved north-eastwards along a cold front over northern England on 6th and outbreaks of heavy rain were accompanied by thunder in parts of north-east England in the afternoon and evening.

A small low passed north-eastwards across central Scotland on 16th and a few thundery outbreaks accompanied the associated cold front as it crossed central Ireland and Lancashire in the afternoon and evening. With a north-westerly airstream covering the British Isles on 17th showers developed in places and there were thunderstorms over eastern Scotland and north-east England, some of which were particularly active. At Rosyth in Dunfermline a 30-year-old man was thrown to the ground when struck by lightning. He reported feeling a searing pain in the back of his head and as he fell saw a bright halo 'sizzling' around his glasses. His teeth felt as if they were being pushed out of his mouth. The unfortunate man was rushed to hospital where he was connected to a heart monitor. He was later released with nothing more than blurred vision and a headache. Small hail fell in a number of places and at Filey Golf Course 10 mm diameter stones fell for 10 minutes and completely covered the ground for a time. After a sunny, quite hot day on 21st cloudy conditions spread from the west in the evening and thunderstorms broke out in parts of southern and western Eire, and over Staffordshire, Cheshire and Greater Manchester. Isolated thunderstorms crossed England during the early hours of 22nd and in the afternoon and evening further thundery outbreaks developed over England and Wales as showers developed behind a cold front. England and Wales had a very showery day on 23rd and some were heavy and prolonged with thunder in south-east Eire and over Wales and the west Midlands. Thunder was also heard at Weymouth in Dorset. Most places had a sunny, very warm day on 31st but cloudy conditions affected Cornwall, south-west Wales and the Channel Islands with thundery outbreaks over West Cornwall in the morning and more widely in the evening.

WORLD WEATHER DISASTERS: August 1991

- 1: Thunderstorms in areas of south-east England; lightning killed a woman at Sevenoaks, Kent, a man was seriously burned by lightning which hit tip of his umbrella at Brentwood, Essex; floods reported in areas of Kent and Sussex; hailstones the size of golf balls fell in areas of Surrey. *Daily Telegraph*.
- 1-6: Severe storms and floods in south-east areas of Europe, brief details below:
 - 1st: A tornado, accompanied by devastating waterspouts, storms and floods hit along a 80 km stretch of coast between Sochi and Tuapse, south Russian coast; at least 30 deaths reported, with 11 others missing, at least 16 of the deaths were by drowning, some rivers rose five metres, sweeping away rail and road bridges and swamping houses and factories.

1st-3rd: Heavy rains caused serious flooding in the Ukraine, a wall of water up to five metres high swept through a rural area near the town of Zastavka, close to the Romanian border, about 50 houses and 100 farm buildings swept away, leaving 11 people dead or missing in the five villages affected, damage put at 43 million roubles.

2nd-5th: Torrential rains and floods in many areas of Austria, described as worst since 1954, five deaths reported; seven of country's nine states affected but worst in Salzburg, upper and lower Austria, Vienna and Burgenland; damage put at £50 million. Railways, roads and bridges washed away, floods along rivers Danube, Salzach, Triesting amongst others, in Vienna the Danube reached a depth of 6.8 metres, at least 10,000 hectares of farmland flooded, floods in Salzburg described as worst since 1959.

2nd-6th: Heavy rains and floods in south and east Poland, a number of bridges destroyed, worst of floods in Bielsko-Biala province, damage put at \$10.4 million.

3rd-4th: Floods left five people dead in southern Germany.

3rd-5th: Rains and floods in Czechoslovakia, the level of the river Danube in Bratislava reached 8.35 metres on the 5th, the third highest this century, much of the surrounding countryside flooded. *Lloyds List, International Herald Tribune, D.T.*

- 2: Cold wave in Uruguay and Argentina, the first snow since 1956 fell on resort of Punta del Este, Uruguay, up to 300 mm of snow fell on resort of Mar del Plata, Argentina; since July 31st, four deaths from exposure in Argentina. *I.H.T.*

- 4: Two vessels, the *Mv. Lane* and the *Mv. Astro Coach*, collided in dense fog about 7.5 nautical miles south of Gibraltar, the *Lane* sank with the loss of one of the crew, the insured loss of the ship and its cargo of 4,580 cars put at around \$70 million. *L.L.*

- 5-10: Renewed rain and floods in areas of China, brief details below:

5th-10th: Rains and floods in Sichuan province, in centre of country, left 456 dead and ruined 1.3 million tons of crops, the floods hit eight cities and prefectures in the south-east of the province.

7th: Storms, with at least two tornadoes, hit in and around Shanghai, leaving at least 16 dead and over 510 injured. One of the tornadoes left seven people dead, over 450 injured, 101 of those seriously, and damaged or destroyed 4800 homes and workplaces in the south-west Shanghai suburbs of Qingpu, Songjiang, Jinshan and Fengxian. The other tornado hit suburb of Wujiang, in the city of Suzhou, 80 km west of Shanghai, injuring 61 people; more than 300 homes were damaged or destroyed. Torrential rains in Shanghai left a further nine dead, in a 24-hour period 230 mm of rain fell on the city, the storm lasted four hours and hit in the evening; meanwhile, floods almost receded in provinces of Hubei, Jiangsu and Anhui; it was reported on the 20th that floods and typhoons in China had left 2903 dead so far this year, with property and

crop losses put at \$12 billion. *L.L., I.H.T.*

- 6: Forest fire in mountains behind the Italian Riviera; a plane fighting the fire crashed just after unleashing its load of water on to fire, some 32 km inland from Savona, leaving the two crew dead. *L.L.*
- 7 (reported): Floods in Myanma (Burma), described as worst for 50 years, have submerged seven towns and left more than 200,000 people homeless in the south-western Irrawaddy Division; the floods followed a week of heavy rains in the Irrawaddy river delta; one person reported dead, about 225,000 hectares of crops, mostly rice, in area damaged. *L.L.*
- 8 (reported): Heavy rains caused widespread flooding along the Amur river in the Soviet Far East, more than 300,000 hectares of farmland under water, including crops that had been mown but not collected, the floods also damaged power supplies and roads in Khabarovsk. *L.L.*
- 12: Floods in Chad and Cameroon, brief details below:
CHAD: Heaviest rains in 30 years fell on town of N'djamena, collapsing houses, leaving 39 dead and 14 seriously injured.
CAMEROON: Rains in northern town of Maroua touched off mudslide which left two dead, in similar flooding in the same area in previous week four people died. *L.L.*
- 13-15: Storms in Bass Strait, between Tasmania and mainland Australia, with winds gusting to 40 knots and 13-metre seas, shipping disrupted; on the 15th a pilot launch, the *George Tobin*, sank in the heavy seas at Port Phillip Heads, Melbourne, Victoria, Australia, leaving three crew dead. *L.L.*
- 14: Heavy rains touched off mudflow on slopes of Mt. Pinatubo, Luzon, Philippines, 96 homes destroyed in Pampanga province, mudflow up to two metres deep. *L.L.*
- 15-17: Typhoon "Fred" moved in Hainan Island, off southern China from the Pacific, brief details below:
15th: The *McDermott Derrick Barge No. 29* sank in typhoon some 105km east of Hong Kong leaving 22 dead, some 180 others rescued.
16th: The *Mv. Biyayang Ginto* sank in typhoon in Hainan Strait in position lat. 20 08N, long. 109 45E., six crew dead, with others missing.
17th: "Fred" hit Hainan Island, leaving 14 dead, 24 injured and damage put at \$12 million, storm then hit southern Chinese mainland. *L.L.*
- 16: Rainstorm, with floods and landslides in the Chamoli district of Uttar Pradesh State, India, left at least 30 feared dead. *L.L.*
- 17: Vessel, the *Mandiri I*, sank in severe storm on voyage from Palembang for Batam, Indonesia, leaving one crew dead, nine others rescued. *L.L.*
- 18-21: Torrential monsoon rains, floods and landslides on Luzon island, Philippines left at least 31 dead, mudslides moved down slopes of Mt. Pinatubo; floods in provinces of Pampanga, Tarlac and Zambales, some 67,000 people fled their homes, many homes destroyed, in town of Bacolor, Pampanga province, lightning killed one person. *L.L., D.T.*
- 18-21: Hurricane "Bob" hit eastern coast of U.S.A. and Canada, brief details

below:

18th: Winds hit North Carolina barrier islands, trees uprooted, flooding in areas and at least two tornadoes, one on Hatteras Island overturned a mobile home and a fish-packing house at Hatteras was heavily damaged, winds in centre of hurricane gusted to 225 km/h.

18-20: "Bob" hit north-east states of U.S.A., with winds gusting to 200 km/h, causing at least 13 direct or indirect deaths and insured losses of at least \$780 million, made up of Massachusetts, \$525m., Rhode Island, \$115., New York, \$75m., Connecticut, \$40m., and Maine \$27m.; more than 180mm of rain fell on Maine.

21: Remnants of "Bob" hit eastern provinces of Canada with winds gusting to 115 km/h., trees and power poles uprooted, no casualties. *L.L., I.H.T.*

20-24: Typhoon "Gladys" hit Japan and South Korea, brief details below:
JAPAN: hit on the 20th-21st with torrential rains, floods and landslides, the floods and landslides, mainly around the Tokyo area, left 10 people dead, at least one missing; the centre of the typhoon remained off Japan's southern coast with winds gusting up to 105 km/h., rail, road and air transport disrupted.

SOUTH KOREA: "Gladys" hit with winds of 90 km/h and up to 600 mm of rain between the 22nd and the 24th., floods and landslides left at least 72 dead, with 30 others missing; south-west of country worst hit, 2000 people made homeless. *L.L.*

23-31: Heavy rains and floods in Kampuchea, the floods, which put 1.1 million acres of land under water in 10 provinces, were described as worst in country's history, damage put at \$150 million and at least 22 deaths reported, worst of floods along Mekong and Tonle rivers, some 33% of Kampuchea's rice crop under water, rail and road links cut, thousands of homes destroyed. *L.L.*

24: M. bulk carrier *Melete* sank in heavy seas in position lat. 27 41S., long 54 13E., some 400 nautical miles south-east of Madagascar, leaving 25 crew missing, two others picked up. *L.L.*

28: Lightning struck electricity pylon at Ozd, Hungary, bringing down cables which hit motorway, rendering 20 people unconscious. *D.T.*

30: Storm with winds up to 80 km/h hit Argentine-Uruguay coast, in Argentina; rain accompanying storm flooded low-lying areas of Buenos Aires, 100 evacuated; off the Uruguay coast a yacht foundered, leaving five people missing, other shipping also in difficulty. *L.L.*

31-1 Sept: Violent storms hit south-west France causing widespread floods and damaging vines. Hail and rainstorms hit the Bordeaux region on night of the 31st and morning of 1st, and more than 4500 lightning strikes registered. Corn fields were damaged, roofs torn off and streets flooded, no casualties reported. *L.L.*

End Aug. (reported): By the end of August, most areas of southern Indonesia had suffered almost four months of total drought. Many reports had been received from all regions of rice dying in the fields, reservoirs becoming

dry, diseases caused by inadequate domestic water, and latterly, forest fires breaking out in Vjung Kulon National Park (West Java) and in East Kalimantan (site of worst forest fire on record, in drought of 1982-83), and locally elsewhere. Worst affected area were Java Bali, Nusatenggara and southern regions of Sumatra, Kalimantan and Sulawesi, no reports of drought received from northern Indonesia. *From our Jakarta correspondent.*

ALBERT J. THOMAS

WORLD WEATHER REVIEW: August 1991

United States: *Temperature:* mostly warm (seventh consecutive warm month); +3degC locally from S. Idaho to N.E. Montana. Cold from most of New Mexico to W. Kansas and W. Tennessee; most of California (-degC locally in both areas); marginally from S. Georgia to W. North Carolina. *Rainfall:* wet in coastal Oregon and Washington; S.E. Idaho to C. Kansas, E. New Mexico, N. Texas, Louisiana and Arkansas; Maine to parts of Delaware; E. Florida; most of Georgia to S. North Carolina, and Hawaii; much of North Dakota. Over 200% in coastal Washington, S. Hawaii, N.E. Texas, N. Louisiana, C. Georgia, N. South Carolina, S. Maine to Connecticut. Dry elsewhere; under 50% general from W. coast to Idaho, W. Utah and W. New Mexico; E. Montana to N.E. Oklahoma; Honolulu.

Canada and Arctic. *Temperature:* mostly war; +4degC in E. Alberta, W. Saskatchewan. Cold in Alaska (except W.), Yukon, Canadian Arctic islands, W. Greenland, Newfoundland; -1degC in N. E. Alaska and fairly widely in the other areas. *Rainfall:* wet in S. Alaska, W. and S.E. British Columbia, S. Alberta, Mackenzie estuary, Greenland, Maritime Provinces, S. Iceland, Baffin Island and some other Canadian Arctic islands; parts of Quebec. Over 200% in coastal British Columbia, Mackenzie estuary, Gulf of St. Lawrence. Dry elsewhere; under 50% in N. and W. Alaska, S.E. Saskatchewan, S. Manitoba, Ungava Bay; parts of E. British Columbia, E. Alberta and W. Saskatchewan. Franz Josef Land near normal.

South and Central America. *Temperature:* mostly warm in South America 15-40°S. and from Mexico to Honduras; +2degC in part of N. Argentina and S. Brazil. Cold in N. Paraguay, Chihuahua area (N. Mexico); most of Bolivia; parts of S.C. and N.W. Argentina and adjacent parts of Chile; -1degC at least locally in all areas except perhaps Chile; -2degC locally from W. Bolivia to N. Paraguay. *Rainfall:* wet around (but mostly not in) Buenos Aires province (Argentina); over 200% fairly widely. Otherwise mainly dry in South America 15-40°S. and from Mexico to Honduras. Under 50% very generally in South America; also N.W. and N.E. Mexico and from S. Mexico to Honduras (except Yucatan to N.W. Honduras).

Europe. *Temperature:* warm in W.; +2degC in much of Portugal and Spain; most of France; E. England, S. Belgium, S.W. Germany, Switzerland; parts of extreme N. Italy, Austria and N. E. Poland; +3degC in interior Spain, S.W. and S.E. France and Switzerland. Cold in European U.S.S.R. (except in and near Baltic Republics); Greece to S.E. Hungary and most of Romania; -2degC in S. Greece and near Urals. *Rainfall:* wet from parts of Norway, N. Sweden and Finland to S. Urals; N.E. Ukraine, N.E. Romania, S. Bulgaria; more widely in Greece. Dry elsewhere; under 50% from Portugal to most of British Isles, Denmark, W. Germany, Switzerland, coastal Yugoslavia and most of Italy; Kola Peninsula to N. Urals; Belorussia; locally near Sea of Azov and near N.W. Caspian Sea. Provisional sunspot number 175.

Africa. *Temperature:* warm from Madeira to N.E. Algeria; Natal, Transvaal, E. Orange Free State; +2degC locally from C. Morocco to N. Algeria. Cold in Tunisia, Cape Province, W. Orange Free State; -2degC locally in N. Tunisia. *Rainfall:* wet in Madeira, N.E. Morocco (both 200% or more). Dry in Canary Islands, W. and S. Morocco, N. Algeria, Tunisia, in and near South Africa. Under 50% widely in all these areas.

Asian U.S.S.R. *Temperature:* mostly warm; +5degC E. of lower R. Kolyma. Cold from

Turkmenistan to Yenisey basin; Sakhalin; -3degC in C. Urals. *Rainfall*: wet from upper Ob basin to Taimyr Peninsular, then to S. Sea of Okhotsk; locally over 200%. Dry elsewhere; under 50% from most of Kazakhsatan southwards; N. Urals to Yenisey Gulf; R. Lena to Bering Strait; much of Amur basin; N.W. of L. Baikal.

Asia (excluding U.S.S.R.). *Temperature*: warm from most of Turkey to most of Iran; N.W. India, N. Mongolia, C. and S.E. China, Taiwan, extreme N. Korea, Thailand, Malaya, Philippines; +2degC in W. Iran; +3degC in E. Mongolia and adjacent part of China. Cold in Cyprus, S. coast of Turkey, Arabia, W. and part of E. China, Japan; most of Korea; -2degC round Qatar, parts of S.W. China. Most of India, Pakistan and Bangladesh near normal. *Rainfall*: wet in parts of W. Turkey; N. India, W. China, W. and N. Mongolia, N. Vietnam, C. and extreme N.E. Philippines; most of Japan and Thailand; part of S. Korea. Over 200% at least locally in all these areas (except possibly India and Korea), especially W. China. Dry from most of Turkey to most of India; E. China, S.E. Mongolia, S. and extreme N. Japan, S. Vietnam, Malaysia, Sumatra; much of Philippines; part of N.W. Thailand. Under 50% at least locally in all these areas except perhaps Thailand and Vietnam; widely from Turkey to India; E. China, Sumatra.

Australia. *Temperature*: mostly warm; +2deg C locally in W. Cold in extreme N. and in N.E. New South Wales (locally -1degC). *Rainfall*: wet from S. and W. Victoria to Adelaide; rarely over 200%. Dry elsewhere; under 50% general except in much of extreme S.

M. W. ROWE

WEATHER SUMMARY: DECEMBER 1991

Over the United Kingdom as a whole mean temperatures were close to the December normal ranging from a little below in parts of England and Wales to a little in excess of one degree Celsius above over parts of Scotland. The highest temperatures of the month were recorded during the week before Christmas with maximum values reaching 15.3° at Finningley (South Yorkshire) and 14.3° at Great Malvern (Hereford and Worcester) on 21st, 15.1° at Sunderland, 14.8° at Buxton (Norfolk) and 14.7° at Dover on 22nd and 12.0° at Inverness, Invergordon and Kinloss in Scotland on 25th. On 22nd minimum values were as high as 12° or 13° quite widely across England and Wales and 10°C was recorded locally in Western Isles of Scotland on 14th. During the second week of the month persistent freezing fog produced some very low maxima with -1.0° at Leeming (North Yorkshire) on 7th, -2.5° at Church Fenton (North Yorkshire) on 9th, -2.3° at Perth (Tayside) on 10th, -4.6° at Finningley and at both Velindre (Powys) and High Bradfield (South Yorkshire) on 11th and -3.1° at Great Malvern on 12th. During two relatively brief polar outbreaks some quite low minima were recorded. The first spell affected mainly Scotland with temperatures as low as -10.6° at Inverdrue and -9.5° at Aviemore (both Highland) on 6th and -8.5°C at Glenlivet (Grampian) on 7th. The second cold plunge produced some low temperatures further south with minima of -9.5° at Elmdon (West Midlands) and South Farnborough (Hampshire) on 11th and as low as -10.8° at Beaufort Park (Berkshire) and -10.4° at Gurney Slade (Somerset), both on 12th. On 13th -9.5°C was recorded at Northolt (Greater London) and Beaufort Park. Lowest grass minima included -13.7° at Inverdrue on 6th, -14.0° at Elmdon on 11th, -15.1° at Brize Norton (Oxfordshire) and -12.4° at Royston (Cambridgeshire) on 12th and -13.1° at Larkhill (Wiltshire) on 13th.

Apart from above average rainfall in parts of south-west Scotland over

almost all other parts of the United Kingdom it was a dry month. Over England and Wales totals were widely below 50 percent and only 19 percent was recorded at Aberporth (Dyfed). The only significant rain during the month fell between 16th and 22nd with 26.2mm at Ventnor (Isle of Wight) on 16th, 29.4mm at Eskalemuir (Dumfries and Galloway) on 17th, 28.0mm at Carrigans (Co. Tyrone) on 18th, 34.9mm at Buxton (Derbyshire) on 20th, 51.5mm at Buxton on 21st and 36.8mm at Lochranza (Isle of Arran) on 22nd. Note that 86.4mm fell on the Derbyshire market town of Buxton during the 48 hours commencing 0900 GMT on 20th.

Western areas had a very dull month and it was exceptionally dull in western Scotland where only 24 percent was recorded locally. Eastern England was quite sunny, especially so in north-eastern counties of England and from East Anglia to London where totals exceeded 130 percent in places.

The first two weeks of December were mostly anticyclonic with centres of high pressure over, and later, to the east and south-east of Britain. For several days there was very little sunshine anywhere, with northern areas seeing just a little, but from 6th clearer skies spread to much of England and Wales as cold continental air spread across the country in the freshening easterly winds. During the course of the second week clear skies at night allowed temperatures to fall well below freezing quite widely and fog, a good deal of it freezing, developed in many places and failed to clear by day in some places. On some days temperatures failed to rise above freezing in places and remained below quite widely over England on 11th. The far north-west of Britain was appreciably milder with south-westerly winds and with some light rain or drizzle at times. Many parts of England had further widespread fog on 14th and 15th but much more unsettled weather spread to western areas on 16th and milder weather with some rain spread to all parts on 17th as a series of frontal systems crossed the country. From 19th to 23rd disturbed weather affected all parts with spells of rain, heavy at times in the north, and especially so across northern England on 21st where widespread flooding occurred. Winds reached gale or severe gale-force at times in central and northern areas and mild weather alternated with much colder conditions when snow fell in northern parts, especially over the hills. Some quite appreciable accumulations of snow were reported on the morning of 20th. The month ended on a quiet, anticyclonic note, but with the centre of the high remaining mostly to the south of the country the air flowing around it was relatively moist and quite mild, and weak frontal systems crossed the country from time-to-time giving northern and western areas a little rain.

K.O.M.

CUMBRIA RAINFALL: Carlisle 84.0mm (113%); Appleby Bongate 74.2mm (82%); Keswick 136.6mm (83%); The Nook, Thirlmere 280.7mm (96%); Coniston 348.5mm (126%); Hawkshead 242.0mm (117%); Windermere, Whasdyke 192.8mm (104%); Grange-over-Sands 121.0mm (102%).

TEMPERATURE AND RAINFALL: DECEMBER 1991

	Mean		Max	Min	Grass	Rain	%	Wettest	RD	TL
	Max	Min								
BELGIUM: Uccle	6.0	1.2	12.7(22)	-5.0(11)	-11.0(15)	70.4	102	20.4(17)	11	-
" Rochefort	4.9	-2.0	11.2(22)	-11.2(14)		96.0	138	36.3(21)	12	-
" Liège	6.4	1.4	13.0(22)	-4.9(11)		86.3	138	23.0(21)	11	-
DENMARK: Fano	6.3	1.8	9.1(19)	-5.2(10)		54.7	71	12.7(18)	13	0
" Frederikssund	5.5	0.4	9.0(23)	-6.2(10)	-9.5(10)	52.4	96	15.0(24)	15	0
FRANCE: Mailly Maillet (Somme)										
GERMANY: Berlin	4.1	-1.0	12.0(23)	-8.8(10)	-10.2(10)	41.2	84	14.0(19)	12	0
" Hamburg	5.2	-0.4	12.4(23)	-6.5(10)	-9.9(12)	98.3	138	33.5(19)	15	2
" Frankfurt	3.8	-1.6	12.7(22)	-11.4(13)	-13.1(13)	46.8	87	11.2(19)	10	0
" München	1.5	-5.2	10.7(23)	-16.8(11)	-20.3(11)	57.7	110	11.9(22)	16	0
MALTA: Luqa	14.3	9.3	18.4 (2)	5.2(15)	-0.3(15)	160.4	143	47.2 (2)	17	3
NETHERLANDS: Ten Post	5.8	0.9	11.7(23)	-5.5(11)	-7.8 (6)	54.8	71	16.6(18)	13	2
SWEDEN: Valla	3.4	-2.3	9.3(17)	-6.3(22)		23.4		5.2(26)	16	0
SWITZ'D: Basel	4.1	-2.2	12.8(22)	-7.9(13)		35.6	81	13.8(17)	9	1
EIRE: Straide	9.1	3.8	14.0(22)	-3.9 (1)	-9.7 (1)	126.4	94	27.6(20)	17	2
" Mt. Russell, Limerick	8.8	4.8	13.3(22)	0.8(20)	-1.2(14)	31.6		7.3(21)	14	3
SHETLAND: Whalsay	7.3	4.0	11.0(13)	-1.1(21)	-6.7(22)	110.9	89	12.5(17)	22	2
" Fair Isle	7.7	5.1	10.4(13)	-0.4(21)	-3.6(22)	75.1	71	11.9(18)	22	0
SCOTLAND: Braemar	6.1	-0.8	10.6(25)	-6.6(30)	-8.2(30)	51.1	52	10.6(31)	10	0
" Inverduie	6.2	-0.6	10.5(25)	-10.6 (6)	-13.7 (6)	59.1	68	17.8(17)	10	0
" Rannoch	5.9	-0.9	10.3(13)	-6.8 (4)	-6.1(11)	114.9		24.0(22)	13	0
WALES: Velindre	6.6	1.5	12.3(21)	-7.5(12)	-10.6(12)	38.9	38	8.4(20)	9	0
" Carmarthen	7.9	3.0	12.2(21)	-7.4(12)	-11.5(12)	41.2	28	9.8(15)	9	0
" Gower	8.1	4.3	11.8(22)	-3.8(12)	-7.9(11)	47.4	35	9.4(16)	11	0
GUERNSEY: Airport	8.7	5.1	11.9(21)	-1.8(11)		28.8		11.9(15)	8	0
JERSEY: Carrefour/Clq	8.6	3.9	12.4(21)	-4.3(11)		37.5		13.6(19)	11	1
ENGLAND:										
Denbury, Devon	8.5	4.4	12.6(21)	-4.0(12)	-8.6(12)	37.7	26	13.5(19)	8	0
Minehead, Som	8.8	3.8	13.8(22)	-5.7(12)	-9.1(12)	28.2	31	6.8(21)	8	0
Gurney Slade, Som	6.6	1.3	12.5(22)	-10.4(12)	-10.8(12)	62.7	51	11.7(20)	11	0
Yatton, Avon	7.4	2.4	13.3(23)	-8.9(12)	-10.4(12)	27.3	29	8.1(17)	7	0
Reading Univ, Berks	7.6	1.5	13.0(21)	-8.9(12)	-12.4(12)	12.3	19	3.8(17)	7	0
Sandhurst, Berks	7.4	0.7	12.8(22)	-9.4(12)	-11.1(12)	14.2	21	8.0(17)	6	0
Romsey, Hants	7.8	1.9	14.0(22)	-8.0(12)	-11.5(11)	18.9	16	5.2(16)	7	0
Brighton, Sussex	7.9	2.7	13.0(22)	-3.9(11)	-4.3(11)	27.2	28	8.6(15)	7	0
Hastings, Sussex	8.6	3.7	13.3(21)	-2.3(11)	-4.8(14)	30.4	38	11.2(16)	5	0
Dover, Kent	8.4	1.6	14.7(22)	-4.5 (7)	-5.5(14)	27.8	30	6.8(17)	9	0
East Malling, Kent	8.1	1.3	14.2(22)	-8.0(11)	-10.5(11)	20.4	33	6.5(17)	10	0
Epsom Downs, Surrey	7.8	1.3	13.2(21)	-9.2(11)	-10.7(11)	12.6		5.4(17)	7	0
Guildford, Surrey	7.0	2.4	13.3(21)	-7.7(11)	-9.1(11)	14.8	20	5.4(17)	9	0
Sidcup, London	8.0	1.2	13.8(22)	-7.4(12)	-11.3(11)	14.4		5.5(17)	6	0
Hayes, London	7.1	1.3	12.9(22)	-8.9(12)	-11.5(12)	17.4	26	6.5(17)	8	0
Hampstead, London	7.3	2.5	12.6(23)	-5.3(12)	-11.4(12)	15.8	24	5.2(17)	7	0
Royston, Herts	7.0	2.4	14.0(21)	-6.5(12)	-12.4(12)	10.3	18	3.6(17)	8	0
Loughton, Essex	6.6	1.0	13.8(23)	-9.1(12)	-15.0(11)	15.4	22	4.2(17)	12	0
Buxton, Norfolk	6.9	1.4	14.8(22)	-7.7(11)	-8.9(11)	32.9	57	10.3(20)	7	0
Ely, Cambs	6.9	-0.3	14.3(22)	-10.0(12)		19.9		6.3(17)	8	0
Luton, Beds	6.8	1.2	12.8(23)	-9.8(12)	-12.6(15)	17.9	27	6.8(17)	8	0
Buckingham, Bucks	6.5	1.0	13.7(21)	-10.9(12)	-15.3(12)	19.9	34	7.0(17)	8	0
Oxford University	7.0	1.6	13.0(22)	-9.7(12)		15.9	29	6.2(17)	8	-
Birmingham Univ.	6.4	2.3	14.0(22)	-7.8(12)	-13.0(12)	14.6		5.9(17)	8	0
Wolverhampton, W.Mid	6.9	1.9	13.1(21)	-7.3(12)	-11.7(12)	16.0		5.6(17)	7	0
Louth, Lincs	7.4	1.9	14.6(22)	-6.2(11)		33.3		11.3(20)	7	0
Keyworth, Notts	7.1	1.4	13.7 (v)	-9.8(12)	-10.7(12)	35.1	57	11.8(17)	7	0
Lowdham, Notts	7.4	1.7	13.3(21)	-7.9(12)	-8.8(12)	31.9	53	9.3(20)	8	0
Derby, Derbys	6.4	2.7	13.4(23)	-7.9(12)	-7.9(12)	52.1	82	17.0(21)	7	0
Middleton, Derbys	5.9	1.7	12.4(22)	-5.4(11)		115.3	97	49.5(21)	11	2
Keele Univ, Staffs	6.6	2.0	13.2(21)	-8.2(12)	-10.0(12)	63.0	112	30.9(21)	9	0
Lathom, Mersey	7.7	2.4	12.8(21)	-4.6(11)		61.2		18.4(20)	6	0
High Bradfield, S.York	5.6	1.1	11.6(21)	-6.8(12)						
Carlton-in-Cleveland	8.0	1.5	13.2(22)	-7.6(12)	-8.4(12)	31.4		8.7(23)	11	0
Durham Univ, Durham	7.7	-0.1	15.1(22)	-9.0(12)		44.6	73	9.2(21)	12	-
Sunderland, Tyne & Wear	8.7	2.7	15.1(22)	-3.8(12)		94.9	75	11.5(21)	10	0
U.S.: Bergenfield, N.J.	7.8	-0.9	17.8 (1)	-11.7(19)	-12.8(19)	34.5		37.9 (3)	11	0
JAMAICA: Kingston	31.4	22.4	33.2 (4)	20.1(28)		16.9	55	14.4(10)	4	0
" Montego Bay	29.2	22.7	30.5 (2)	20.9(29)		32.3	31	12.3(18)	6	0
AUSTRALIA: Leopold, Vic	21.7	11.8	34.8(26)	7.1 (5)		115.1	234	27.5(16)	7	1

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CONTENTS

PAGE

Possible ball lightning colour photograph from Sankt Gallenkirch, Vorarlberg, Austria. A. G. KEUL.	73
The rainfall record of the San Fernando Observatory, Cadiz: 1805-1990. DENNIS WHEELER.	82
Climate and population in temperate and cold areas. R. A. BECK.	90
Atmospheric Rydberg's matter as a possible model for ball lightning. M. I. OJOVAN.	95
The Shetland hurricane of 1 January 1992. S. G. IRVINE.	96
Persistent winter high pressure in the British Isles. JOHN TRENCHARD.	96
TORRO thunderstorm report: July 1991. K. O. MORTIMORE.	97
TORRO thunderstorm report: August 1991. K. O. MORTIMORE.	100
World weather disasters: August 1991. A. J. THOMAS.	101
World weather review: August 1991.	105
British weather summary: December 1991.	106
Temperature and rainfall tables: December 1991.	108

FRONT COVER:

A photograph of possible ball lightning taken in Austria
(see the paper by Alexander G. Keul).

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