Deaths and injuries from lightning in the UK, 1988–2012

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Introduction

To assess the lightning risk to people in the UK, a 25-year database (1988–2012) has been compiled of incidents in which people experienced an electrical shock due to lightning. Details of the lightning incidents were extracted from local and national media reports, meteorological and medical journals, internet reports, personal statements sent to the authors and information passed to colleagues in the Tornado and Storm Research Organisation (TORRO).

Total number of incidents and people struck

From 1988 to 2012 there were 445 known incidents of lightning strikes to people in the UK, averaging 18 per annum. Inevitably, this is an underestimate of the actual number of incidents in which a person experienced an electrical shock due to lightning. For example, someone who felt a small electrical shock, from which they quickly recovered, may not have considered it significant enough to mention to anyone other than their family and friends and, consequently, no lasting record may exist. In contrast, serious injuries and fatalities are more likely to be publicised and so be recorded in the database.

Twenty-eight per cent of incidents involved more than one person being struck, increasing the total number of people struck to 722, averaging 29 people per annum. The highest known annual total was 83 people in 1994, an exceptional year for thunderstorm activity when around 550 000 cloud-to-ground strikes were recorded for the British Isles (Elsom, 2001). Given the limitation of the database, the actual annual average of people struck may be significantly more. Since 2007, the Health and Social Care Information Centre (HSCIC) has published annual National Health Service (NHS) Hospital Episode Statistics of 'victims of lightning' (code X33), which includes inpatients, outpatients and accident and emergency attendees. For the period of May to the following April each year, the totals were 60 in 2006/2007, 44 for 2007/2008, 59 for 2008/2009, 75 for 2009/2010 and 75 for 2010/2011 (annual average of 63 for this 5-year period). However, these totals include people taken to hospital with lightning-initiated, but non-electrical, injuries.

Lightning's potential to cause injury

Cloud-to-ground lightning strikes (Figure 1) may result in people experiencing an electrical shock through several ways:

Direct strike. Although lightning is a potentially lethal high-voltage electric current, it has contact with a person for only milliseconds, unlike the longer lasting impact of the continuous current experienced if someone touches a bare wire of an indoor electrical circuit or an outdoor power cable. The short-lived electric current from a direct lightning strike discharge may simply pass over the surface of a person's skin or clothes without most of it penetrating the body. This 'flashover effect' explains why some people do not suffer severe burns or other serious injuries. Unfortunately, there are occasions when a large amount of the current penetrates the skin causing serious burns and major damage to internal organs such as the heart, lungs and brain, which may lead to cardiopulmonary arrest and death. Why a direct strike leads to most or all of the electrical discharge penetrating the body rather than flashing over its surface is not fully understood, although wet skin and clothes provide a better conducting or flashover path than when they are dry. On some occasions the flashover effect leaves a fern-like erythema (reddening of the skin) called a Lichtenberg figure, a phenomenon first described by Georg Christoph Lichtenberg in 1777. Electrons from the lightning are driven into the epidermis and radiate outward from successive points in a fractal pattern of repeated bifurcations (Figures 2 and 3). It does not usually appear until half an hour or several hours after the lightning strike. It is not a burn and disappears within a few hours to 48h. Carrying or wearing small metal objects (e.g. necklace, bracelet, ring, earrings, body piercing stud, belt buckle, keys) does not make a person more likely to be struck. Rather, the objects may cause burns, sometimes in the shape of the object, on those parts of the body they are in close contact with because the metal heats up rapidly to very high temperatures. Very thin metal objects, such as

Figure 1. Lightning strikes the ground over the Brendon Hills, observed looking northwest from Wellington (Somerset) on the evening of 25 June 2009. (© Matt Clark 2013.)

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Figure 2. Lichtenberg figures on the right side of the neck, chest, abdomen and arms of a 30-year-old woman. She had been using a corded telephone when lightning struck her house in Galway (Republic of Ireland) in December 1999. Her right lower leg also showed Lichtenberg figures (not shown). (Source: Mahajan et al., 2008. Reproduced by permission of Elsevier, license number 3244861387161.)

Figure 3. Lichtenberg figure on the left arm of a 10-year-old girl who was touching a metal sink when lightning struck the building in Summerston, Glasgow, April 2008. (Reproduced with permission of Department of Medical Illustration, NHS Greater Glasgow, Yorkhill, and family.)

a necklace, may even be vaporised. Using ear phones or a mobile phone may not only result in minor burns around the ear and cheek if that person is struck by lightning but some medical researchers suggest they may disrupt the flashover effect and lead to some of the electric current entering the head and causing injuries. Burns may be worsened if clothing or hair catches fire or when polyester clothing (e.g. some sports shirts) or plastic objects (e.g. bracelets, hair grips) melt. When lightning strikes a person, the electrical current may follow a line of sweat, as a moist skin surface is a better conductor than adjacent dry areas of skin. The heat generated by the current may cause this moisture to vaporise instantly, causing minor burns in sweaty parts of the body, such as down the mid-chest and spine, beneath the armpits and breasts, and around the groin. If such sudden explosive evaporation takes place on sweaty feet in the confined space of tight-fitting footwear then socks may be ripped and footwear torn apart.

Contact voltage (touch potential). This occurs when a person experiences an electrical shock because they are in contact with an outdoor object struck by lightning (e.g. gate, fence, tree, umbrella, golf club, fishing rod and even another person) or an indoor object that is part of a conducting route for the lightning discharge to reach the ground. This may be a telephone, television or other appliance connected to the electric circuits, or a radiator, tap, sink or shower connected to metal plumbing pipes. Contact voltage may cause a similar range of effects to people as those associated with a direct strike, but indoor incidents usually involve building occupants experiencing a smaller electrical current. This is because electrical circuits and appliances may be protected from excessive voltages by surge arrestors and because the lightning discharge to a building may take several routes to earth.

Side flash (splash). When lightning strikes an object, the electrical current being conducted can jump or splash to a nearby person when their body and clothing offers a better conducting route to earth than the object itself. The outdoor and indoor objects carrying a lightning current and giving rise to a side flash are typically those listed for contact voltage strikes. The potential effects are similar too.

Step voltage effect (ground current). When lightning strikes the open ground, a tree, post or another person, the electrical current spreads outward from the strike point rather like ripples spreading out from a pebble dropped in a pond. For someone within the field of propagating electrical ripples, a voltage gradient or differential is produced between their feet (when at an angle to the ripples). This induces an electrical current up one leg and down the other as the human body offers less resistance for the current to pass through than the ground beneath. Leg muscles spasm violently and a person may be thrown off their feet, sometimes resulting in cuts, bruises or fractures when hitting the ground. Victims may find it difficult to stand as they continue to experience numbness or paralysis in their legs for minutes or even hours after the lightning has struck. The ground current experienced is greater the wider apart the feet (and the closer the feet are to being at right angles to the propagating ripples), the closer to the lightning strike point, the higher the voltage, current and duration of the lightning strike, and the higher the soil resistivity (sand has a higher resistivity than clay, and drier soil more than moist soil). The ground current may affect people up to 30m from the strike point and may account for many

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of the incidents in which a person believes they have experienced a direct lightning strike. Fortunately, the effects of the ground current on people are often, although not always, less serious than a direct strike. Entire sports teams have been thrown to the ground by the step voltage effect.

Upward streamer not connected to a downward stepped leader. Unconnected upward streamers may cause hair to stand on end and objects to buzz or crackle and, in extreme cases, be sufficiently intense to cause minor injuries. The streamer discharges upward from the highest part of the body so the electrical effects of intense streamers on the head are of particular concern, especially given the sensitive nature of the eyes to electrical currents. The current generated by unconnected upward streamers is a tiny fraction of that of, say, a direct lightning strike. Research continues to explore the nature of this effect (Cooper, 2002).

Subsequent electrical discharge from an insulated object. If a metal roof, platform or wire is insulated from the ground then it may temporarily retain the electrical charge from a lightning strike. If a person subsequently touches the object then the charge may be discharged through them to the ground.

Lightning may cause injuries through various non-electrical effects. The sudden explosive expansion of air around the lightning channel may cause blunt trauma injuries when a person is thrown off their feet. This pressure or shock wave may cause deafness due to rupturing of the eardrums, and it may burst soft tissue and cause fractures, typically to the feet. Intense magnetic fields are generated around the lightning channel by the very high electrical currents present. These may induce large but short-lived electric currents in a body causing the heart to stop or go into rapid ventricular fibrillation. It is suggested this may be responsible for the death of healthy young climbers and hikers who have been found dead with no marks on their bodies, although research continues into this effect (Cherington *et al*., 1998).

Other indirect effects of lightning on people in which no electrical shock is experienced include injuries caused by falling roof tiles and masonry when lightning damages a building. Fires initiated by lightning discharges overheating electrical circuits and appliances in buildings may result in the occupants suffering burns and the effects of smoke inhalation. Lightning striking near a motor vehicle, especially at night, may temporarily blind the driver causing them to lose control of the vehicle and resulting in an accident. Farm animals may stampede if frightened by lightning and thunder, injuring people nearby. Lightning hitting a tree may instantly vaporise sap, causing strips of bark and branches to be ejected explosively, which may strike people nearby and result in injuries (Elsom, 1996).

Outdoor versus indoor incidents

The location of each incident in which people experienced an electrical shock due to lightning was assigned to specific categories (Tables 1 and 2). The broad breakdown of the 445 incidents was 223 outdoors, 202 indoors, 4 inside an enclosed vehicle, 2 inside an aircraft (glider) and 14 incidents where the location was unclear. Excluding the latter 14 incidents, 52% of incidents occurred outdoors in the open air and involved 64% of the total people struck. This is because 38% of outdoor incidents involved more than one person being struck, whereas few indoor incidents (17%) did.

A noticeable difference between outdoor and indoor incidents is the gender of those struck. For all incidents where the gender is known, the breakdown was 64% male and 36% female. For outdoor incidents only, 73% of people struck were male. If only fatal incidents are considered, males accounted for 83%. This reflects a higher proportion of male participation in activities being undertaken at the time of the strike (construction work, farming, hill walking, golf, football). In contrast, indoor incidents affected men and women equally (49% male, 51% female).

Table 3 highlights that 44% of all known outdoor incidents resulted in serious injuries or even death but only 2% of all indoor incidents were serious and none were fatal.

Outdoor incidents

Too often people put themselves at risk by sheltering under a tree during a thunderstorm (Table 1) even though many know they should not do so. On 1 July 1994 at Abbeyfield Park, Kenilworth, Warwickshire, lightning struck a tree sheltering five teenagers. A boy closest to the tree died five days later in hospital from his injuries. One girl, who survived after being knocked unconscious, had commented just before the lightning strike that they ought not to be sheltering under a tree because of the increased risk. Being near or sheltering under a tree was responsible for one in five fatalities (Table 4). When incidents involving being struck near a tree are apportioned to the wider location in which the tree was located (Table 1), it is evident that nearly one-third of all outdoor incidents occur in sports and recreation grounds and parks.

The tree location is a separate category in Table 1 because of its likelihood in providing a contact point for a lightning strike. The stepped leader that first makes contact with the positive streamers from objects on the

Table 1

Locations of all outdoor (in the open air) lightning incidents (percentages are rounded to nearest whole number).

Type of location	*% of total outdoor incidents*	*% when 'tree' incidents are assigned to other locations*
Near or under a tree	16	—
Mountain, hilltop, moor or clifftop	11	11
Low-lying farmland or countryside	5	6
Golf course	13	16
Sports or recreation ground, park or race course	20	31
Urban setting (street, car park, driveway, lawn, yard, allotment) excluding above categories	20	21
Near, in or on (a floating object) water, e.g. canal, river, lake, sea	11	12
Other, e.g. airfield, rural railway level crossing	4	4

Table 2

Locations of all indoor lightning incidents (percentages rounded to nearest whole number).

Location	*% of total indoor incidents*
Near, holding or touching a corded telephone	26
Near or touching computer equipment	5
Near or touching electrical equipment, e.g. electrical circuits, fuse box, television, aerial socket, kettle, iron	13
Near or touching a window or external door	15
Near or touching a large object with metal pipes, e.g. radiator, sink, shower, bath	15
Other (e.g. in bed) or unspecified	25

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Table 3

Lightning effects on people outdoors and indoors (based on the 'worst' recorded medical impact known for each incident).

Medical effects	*Outdoors (% of incidents)*	*Indoors (% of incidents)*
Death	21	0
Cardiopulmonary arrest but resuscitated	7	0
Serious (full-thickness) burns; brief unconsciousness; severe fractures; spinal injuries	16	2
Minor burns; temporary damage to eardrums (deafness) or eyes; knocked off feet causing minor blunt trauma (e.g. bruising of arms or legs); temporary weakness, numbness or pain in shoulder, arm or leg; minor electrical shock	56	98

Table 4

Locations of fatal and potentially fatal incidents, 1988–2012.

Type of location	*% of total incidents with a fatality*	*% of total incidents with a fatality or with someone who was resuscitated*
Near or under a tree (in one of the locations below)	20	20
Mountain, hilltop, moor or clifftop	22	18
Low-lying farmland or countryside	7	7
Golf course	7	8
Sports or recreation ground, park or race course	20	20
Urban setting (street, car park, driveway, lawn, yard, allotment) excluding above categories	9	10
Near, in or on (a floating object) water, e.g. canal, river, lake, sea	13	15
Other, e.g. airfield, rural railway level crossing	2	2

ground tends to step towards the ground in 20–50m steps. This makes a 20–40m-high tree a strong contender to provide the initial contact in a relatively open location such as a park, golf course or farmland. In contrast, holding an umbrella, golf club, fishing rod or spade in an open location is a significantly lesser likely attachment point for the stepped leader than a tall tree would be. Even so, the upward streamers arising from, say, someone holding an umbrella are greater than the flat ground within a radius of say, 2 to 3m and so increases the risk of becoming an attachment point if lightning was about to strike anywhere within that small radius.

The largest group of people struck outdoors between 1988 and 2012 took place at Aylesford, Kent, on 2 September 1995. When a thunderstorm interrupted an under-10-year-olds' football match, some of the players and spectators took shelter under a tall tree while others went inside a nearby building. A side flash from the tree struck a man holding a large umbrella. He was amongst a group of four adults and 13 boys who were treated for the effects of the lightning strike – combinations of the effects of a side flash from the tree to the umbrella, side flash and/or contact voltage effect from the umbrella or other people, and the step voltage effect. Many had burns and some had damage to their eyes and experienced difficulty walking. Six of the 17 patients who were taken to hospital recovered quickly and were discharged. The other 11 people were admitted for further treatment with eight being discharged after 12–24h. The remaining three had suffered cardiopulmonary arrest but were resuscitated with external cardiac massage and expired air ventilation. One of these, an eight-year-old boy, had to be resuscitated twice. He also suffered 18% full-thickness burns to his back and buttocks which required a two-week stay in hospital. Tiny, circular, full-thickness burns were evident on the sides of the soles of the feet and tips of the toes on many of the patients, indicating points at which the electrical discharge arced to the ground from those individuals. Lichtenberg figures were present on the lower thorax of one person. Three of the adults suffered lower limb paraesthesia (tingling and numbness) lasting from 1 to 12 weeks, while some individuals experienced one or more of the following: amnesia, confusion, panic attacks (during thunderstorms), depression, mood swings and even psychotic behaviour (Webb *et al*., 1996; Fahmy *et al*., 1999). This case-study highlights that lightning victims can experience long-term health consequences that, in addition to those effects already mentioned, may include sight deterioration, cataracts, tinnitus, partial deafness, sleep disturbance, anxiety, irritability, attention deficit, memory deficit, dizziness, fatigue and psychological problems.

The largest group to be struck in the UK in the past 60 years took place at Ascot race course on 14 July 1955. Twelve people were rendered unconscious for more than a few moments, two of these died from head injuries, and a total of 46 people were taken to local hospitals – although nine had recovered by the time of their arrival. Lightning had struck a tea stall and was seen to run along the race course railings (Arden *et al*., 1956).

Someone caught on a mountain, hilltop, moor or clifftop during a thunderstorm is very exposed to the dangers posed by lightning. Three deaths occurred in three separate lightning incidents on 1 May 1988, two near Helvellyn, Cumbria, and one on Caradoc Hill, Shropshire. Other walkers with the victims suffered burns. Two-thirds of all lightning incidents during 1988 to 2012 in these exposed locations resulted in serious injuries or death to one of the people involved.

Golfers now receive a warning from a klaxon when lightning threatens and are required to discontinue play immediately and head for the club house, avoiding walking under trees or near metal fences. Unfortunately, some still choose to shelter under a nearby tree. Two such golfers were struck by a side flash from a tree on 22 June 2003 in Northampton. One had to be resuscitated by paramedics but died four days later in hospital.

An enclosed vehicle provides a relatively safe location because of the screening (Faraday cage) effect provided by the metal bodywork. The lightning discharges to ground via the bodywork and tyres although the bodywork may suffer pitting where the lightning first made contact and the tyres may be damaged. On rare occasions, the electrics may be damaged and a fire started.

Lightning strikes commercial aircraft on average once or twice a year but passengers and crew are protected as the electrical discharge passes over the body of the aircraft before continuing to the ground. On rare occasions, minor damage may occur and, if suspected, the pilot will normally land the aircraft for an inspection to be undertaken before flying onward. There were no known UK incidents from 1988 to 2012 in which crew or passengers of commercial aircraft are known to have experienced electrical shocks, but there were two

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incidents involving gliders. The more serious occurred at a height of 760m near Dunstable, Bedfordshire, on 17 April 1999. Lightning caused the right wing to fall away, stripped some of the glass fibre skin from the fuselage, and fused the control rods. The pilot received burns to his head and neck, and he and his trainee suffered damaged eardrums, but both ejected and landed safely.

Indoor incidents

Although a direct lightning strike may occur through an open window or door, most individuals inside a building who receive an electrical shock do so because lightning strikes the building, or near to it, and this gives rise to an electrical current surging along electrical or plumbing circuits. Occupants may experience a contact voltage effect, or a side flash, from these circuits or metal objects connected to them such as radiators, sinks, telephones and computers. The electrical shocks experienced may not carry the full lightning discharge as surge protection devices on telephone lines and electrical and electronic equipment may reduce excessive voltages, and lightning may take more than one route to earth through the building.

Around one-quarter of all indoor incidents happened when the victim was touching or holding a corded telephone (wires connect the handset to a base), whether in the home, office or telephone exchange (e.g. seven telephone exchange operators in Kirkaldy, Fife, on 14 July 1995). Of the 56 incidents for which gender is known, 70% were female and 30% male. Typically, telephone users experience an electrical and acoustic shock: they often hear a loud bang or click. They may be thrown to the ground by the violent muscular reaction to the electrical shock. They may be knocked unconscious briefly, suffer temporary loss of hearing and burns to the head or upper body, and suffer cuts and bruises as a result of their fall (Elsom, 1996). The nature of the injuries sustained is influenced by the proximity of the handset to the victim's ear (Elsom, 2001). Victims of such strikes may experience problems with their eyes or ears in the months or even years after the incident. A nine-year-old boy using a telephone in his home in Doncaster on 8 June 1992 lost consciousness for a few seconds and suffered superficial burns to his right cheek and forehead. In the months following the incident he suffered blurring in his right eye and 18 months later had to have an operation for a cataract (Dinakaran *et al.*,1998). Using a cordless telephone or mobile (cell) phone indoors when lightning strikes the building or close by does not result in an electrical shock to the user because it is not connected to the electrical or telephone wire circuits. Using a mobile phone outdoors during a thunderstorm is inadvisable because, if someone is struck by lightning, the phone may cause minor burns in and around the ear and cheek. Of more significance, it may disrupt the flashover effect and direct some of the electrical discharge into the ear and head.

Figure 4. Lightning discharges adjacent to the coast can be spectacular, as in this case looking west from Charmouth, Dorset, late on 22 July 2013, but should be observed from a safe location. (© Matt Clark 2013.)

Lightning fatalities

There were 47 fatalities during the 25-year period, averaging two deaths per annum. Annual variation ranged from none in 2000, 2001, 2007, 2008, 2010 and 2011 to five deaths in 1994 and 1996. All fatalities occurred outdoors (Table 4). Around four in five (79%) fatalities took place during four months: May 21%, June 17%, July 15% and August 26%. This reflects the seasonal incidence of thunderstorms and the increased number of people outside during these months.

Only two of the deaths occurred during the same incident, late afternoon on 22 September 1999 at Hyde Park in London when two women were struck while sheltering under a 20m-high maple tree. They were not discovered until the next day. One was found with her back resting against the tree trunk and it was believed they had been holding hands. Both had severe burns as well as Lichtenberg figures.

The administering of cardiopulmonary resuscitation (CPR) to a lightning victim *in situ* resulted in 17 people (in 15 incidents) surviving between 1988 and 2012. The death toll from lightning would otherwise have been 64 people for this 25-year period. However, even when prompt help is given and the casualty is taken to hospital, injuries to their major organs may be so severe that they die later in hospital. Six of the 47 deaths occurred in hospital intensive care units three to six days after being struck by lightning and one 12-year-old boy died three weeks after being struck playing rugby (8 October 1993 at Crewkerne, Somerset).

The average annual number of deaths for the period 1988–2012 in the UK was two people. This is around half that of the period from the 1960s to 1980s (Elsom, 1993; 2001). Some of the reasons for this are: a continued reduction in the number of people employed in outdoor occupations such as agriculture; strengthening of health and safety regulations for outdoor workers; more buildings required by regulations to install lightning protection; improved aircraft safety; and lightning warning systems on golf courses. There is also improved medical attention for lightning casualties, including more people knowing how to administer CPR, paramedics and ambulances reaching casualties more quickly and being better equipped to give emergency treatment and using helicopters to transfer casualties to hospital from remote locations such as mountains. There is increased awareness of the danger posed by lightning as a result of school and public education (e.g. The Royal Society for the Prevention of Accidents, 2007). Individuals and organisations responsible for their members (e.g. sports clubs) are now more disposed to reschedule or discontinue their activities when thunderstorms are forecast or develop in their area. Public confidence in thunderstorm forecasts has improved as their accuracy has increased and such forecasts have become more readily available. Even so, it is important that precautionary awareness of the lightning risk continues to increase so as to offset the growing numbers of people participating in outdoor leisure interests such as golf, fell-walking, climbing, mountain biking and water sports, which put more people in exposed open areas (Figure 4).

Summary

From 1988 to 2012 there were, on average, 29 people known to have experienced an electrical shock due to lightning per annum

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in the UK, of which two died. There are probably many incidents involving minor injuries that were not recorded. Consequently, the actual number of people struck each year may be significantly greater. Just over half of all incidents occurred outdoors but, because many of those incidents involved more than one person, they accounted for two-thirds of the total number of people struck during the study period. Whereas very few indoor incidents resulted in serious injuries and none were fatal, nearly half of all outdoor incidents resulted in serious injuries or even death.

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Letters

Readers are encouraged to submit letters for possible publication. Letters can be submitted either electronically through the system used for articles, by email attachment to weather@wiley.com or by post, as shown on the Contents page. The Letters Editor reserves the right to edit any letter.

The 1923 edition of the Ward Lock guide to Anglesey and North Wales is most upbeat on the winter climate of the North Wales coast and in the Llandudno section it states that *William Marriott, Secretary of the Royal Meteorological Society, has analysed records and found that the winter climate is equally favourable in terms of temperature to any of the popular south coast resorts*. It also states in another section that Llanfairfechan along the coast to the west between Conwy and Abergwyngregyn can out do its North Wales rivals.

Today (here in Llanfairfechan) we sit a couple of degrees above the North Wales norm, but earlier in December we did much more than that by reaching 17.0°C at around 0130 UTC on the morning of the 12th in a föhn wind (Figure 1). It seems that as the long-established high slipped east and the southerly flow edged in from the west, the temperature inversion height was just right for the air flowing down to the coastal strip to have its source from above the inversion. All reports in this area recorded around 17°C as an overnight maximum. At the same time the humidity fell to 24% with a dew point of –4.4°C. Interestingly late in the afternoon of the 12th after a shallow dip the temperature rose again in the eastern part of the area to around 17°C, but this time there was no drop in humidity (all reports viewable on the Met Office Weather Observation Website for 11 and 12 December 2013).

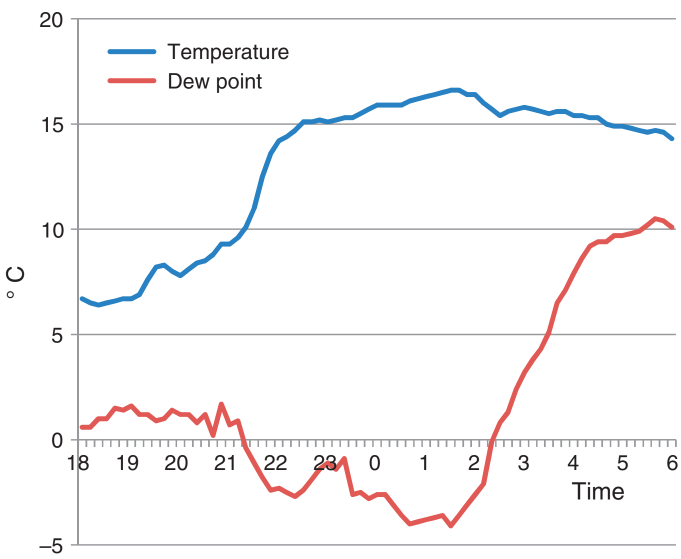

Figure 1. Temperature and dew point from 1800 UTC on 11 December to 0600 UTC on 12 December 2013.

I have been running a Davis Vantage Pro2 for 2.5 years, but in November I installed a Stevenson screen and glass thermometers so that I could measure these winter wonders in the standard manner. Fortunately I have not missed any in recent years and this may be the highest since at least 1998.

David Lee
Llanfairfechan, Conwy

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