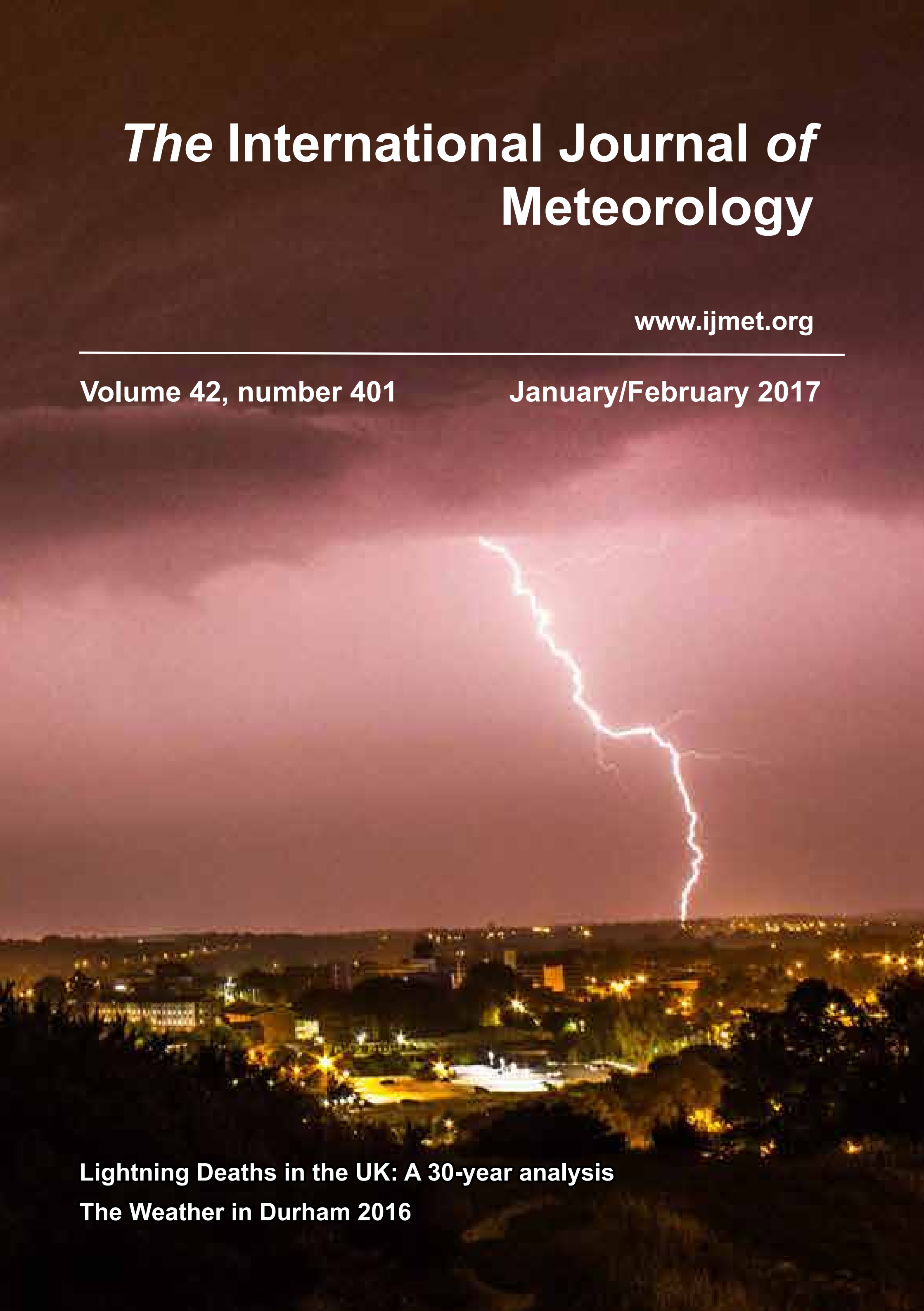

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Lightning Deaths in the UK: A 30-year analysis

The Weather in Durham 2016

Extreme Weather

Forty Years of the Tornado and Storm Research Organisation (TORRO)

Robert K. Doe

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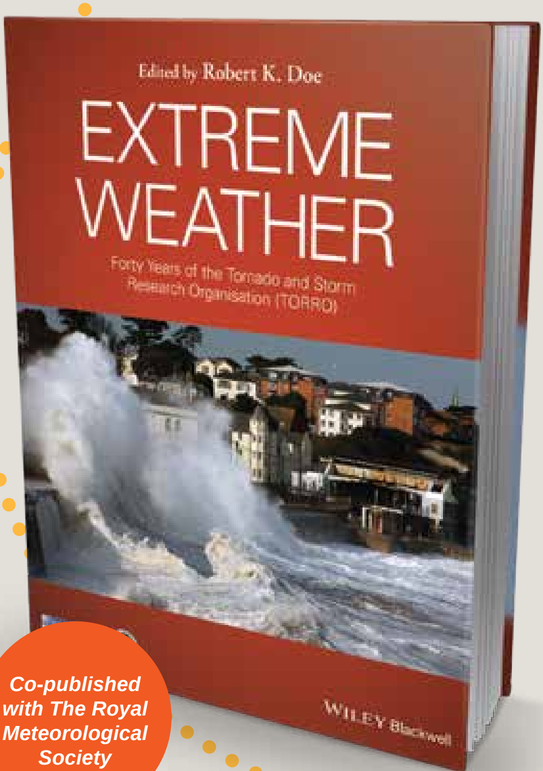

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Cover image: © **DAN HOLLEY.** Lightning strikes just west of Norwich during the early hours of the 19 July 2017.

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WEATHER ANNIVERSARIES: JANUARY/FEBRUARY

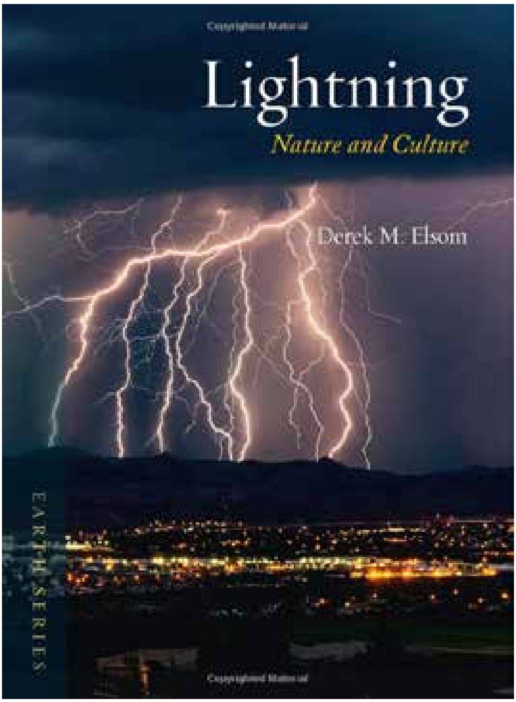
25 years ago, the New Year of 1992 came in with a tremendous hurricane in the Northern Isles in the early hours of 1 January as a deep depression moved rapidly across the Faeroes. Gusts of 95 knots were recorded at Baltasound and Lerwick, and 98 knots at Sumburgh; hourly mean winds reached 60 knots or more. Structural damage throughout the islands included destruction of the early-warning radar domes on Saxa Vord Hill (Unst). There were large orographic rainfalls in the Western Highlands, where Achnagart (in Glen Shiel) had 155.5 mm on the 1st and 105.5 mm the next day. Despite this wild start January was predominantly anticyclonic, and monthly mean pressure exceeded 1030 mb in southeast England. Severe frosts occurred in the second half of the month, and persistent fog kept daytime temperatures near freezing in the last few days. Pressure was again high in the south in February (for the third month running), and it was often mild, but there was a snowy spell in the north in mid-month. Rainfall was well above average in western Scotland (falls of over 75 mm on the 21st) but it was another dry month in southern England, where the winter was one of the driest on record.

50 years ago, northerly winds brought frost and snow in the first part of January 1967. There was 5-10 cm of snow in the north and east in the second week and night-time temperatures of −5 to −10°C; but the rest of the month was milder with occasional rain. The first half of February was mainly quiet and dry but there was a severe gale in the north on the 3rd (gust 81 knots at Kirkwall). The second half was much more disturbed as vigorous depressions passed over the British Isles. Gales occurred somewhere on most days from the 18th onwards, gusts including: 79 knots in the Isles of Scilly on the 19th, 69 knots at Jersey on the 20th, 65 knots at Binbrook (Lincs) on the 23rd, 72 knots at Turnhouse (Edinburgh) on the 27th and at Valley (Anglesey) on the 28th; several tornadoes were recorded in this period. There were blizzards in the north on the 22nd/23rd as a deepening depression crossed northern England. The 27th was a very wet day in the western hills, where many stations received 50-100 mm of rain (112.8 mm in Snowdonia); and thunder was widespread on the last two days of the month in a strong westerly airstream.

75 years ago, the winter of 1941/42 was the third cold one in a row. January 1942 was characterised by troughs moving in from the Atlantic then stagnating over the British Isles; the weather often remained cold, and at times snowy, in the east while the west had milder spells. It was a wet month nearly everywhere (200% in some parts) but northwest Scotland was drier than usual. Widespread snowfall and blizzards occurred about the 19th-21st resulting in mean depths of 15-30 cm in many places and up to 60 cm in southern Scotland. −15°C was recorded at Woburn (Bedfordshire) on the 21st. February was much drier (only 10% of normal rainfall in southwest England) under the influence of high pressure but the cold weather became more persistent. A slow-moving shallow trough in the early days of the month produced heavy snowfalls in eastern

Scotland and northeast England, where mean depths reached 25 cm or more and there were large drifts; and although falls during the rest of the month were mostly small, the ground here remained snow-covered for much of this time. Frost occurred frequently and was severe at times (−14°C in County Durham on the 8th).

100 years ago, January 1917 began with mild westerly winds but a depression moving south through the North Sea in the second week was accompanied by northerly gales and introduced much colder weather, which persisted for the rest of the month. From mid-month pressure was high to the north of the British Isles and easterly winds prevailed. In northeast England 20-30 cm of snow was lying by mid-month; and the approach of a depression towards the southwest on the 25th resulted in a severe blizzard in the south and west of Ireland, where mean depths of 30 cm or more were reported. Glazed frost affected the Home Counties on the 22nd. Frost intensified in the first week of February, which was a mainly anticyclonic month and very dry; January's snow remained on the ground for some time but amounts of fresh snow were small. Frost, however, was very severe at times. Temperatures fell below −10°C in many places from the 5th-7th and were as low as −20°C at Benson (Oxon) on the 6th; other widely separated parts of Britain recorded between −16 and −19°C, and day maxima of 0 to −5°C were general at this time. The second half of the month was less cold.



In **Lightning: Nature and Culture**, ***Derek M. Elsom*** explores the history of humanity's relationship with this natural phenomenon - from the myths and legends of the storm deities, to in-depth studies of its artistic representations, to state-of-the-art lightning protection systems on aircraft, ships and skyscrapers. Lightning: Nature and Culture will appeal to all those interested in the natural environment, especially those fascinated by extreme weather forces and how weather is an integral part of our daily lives.

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LIGHTNING DEATHS IN THE UK: A 30-YEAR ANALYSIS OF THE FACTORS CONTRIBUTING TO PEOPLE BEING STRUCK AND KILLED

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ABSTRACT
In the UK in the past 30 years (1987-2016), 58 people were known to have been killed by lightning, that is, on average, two people per year. The average annual risk of being struck and killed was one person in 33 million. If only the past ten years are considered, a period with fewer average lightning deaths, the risk was one person in 71 million. The likelihood of being killed by lightning is much less than it was a century ago when it was around one person in every two million per year. The current UK lightning risk is compared with USA risk. The risk of being killed by lightning in the UK differs by the activity being undertaken at the time. This paper groups activities into three broad types. During the past 30 years, work-related activities accounted for 15 per cent of all deaths, daily routine for 13 per cent, and outdoor leisure, recreation and sports pursuits for 72 per cent. Leisure walking on hills, mountains and cliff-tops together with participating in outdoor sports activities, notably cricket, fishing, football, golf, rugby and watersports, gave rise to around half of all leisure, recreation and sports activity deaths. The highest number of deaths occurred amongst the 20-29 year-age-range. Men accounted for 83 per cent of all lightning deaths reflecting the higher proportion of male participation in outdoor work-related activities and specific outdoor leisure activities (hill and mountain walking) and sports activities (cricket, fishing, football and golf). Sundays gave rise to 26 per cent of all deaths reflecting this is a day when large numbers of people participate in higher lightning risk leisure activities. The four months from May to August accounted for 80 per cent of all deaths. A specific study is conducted of the synoptic and weather situations during days when thunderstorms developed and resulted in deaths amongst people undertaking leisure walking activities. Overall, this paper highlights the factors that should help to lessen the risk of being killed by lightning in the future.

Keywords: *Lightning deaths, lightning fatality rates, lightning risk, lightning safety, UK/USA comparison*

INTRODUCTION

To better understand the factors contributing to people being killed by lightning in the UK, this article analyses known lightning deaths for the past 30 years (1987-2016) using official national statistics and the Tornado and Storm Research Organisation (TORRO)'s National Lightning Incidents Database. It extends the findings of Elsom and Webb (2014) who provided the first detailed analyses of both lightning deaths and injuries in the UK using a recent 25-year period (1988-2012). The results in this paper are compared with the USA for the same 30-year period.

DATA SOURCES

The annual number of lightning deaths is provided by the Office for National Statistics for England and Wales (available from 1852 to the present), the Northern Ireland Statistics and Research Agency (1964 to present) and the National Records of Scotland (1951 to present). They are based on death certificates registered in the UK in which lightning is the 'underlying cause of death' (Figure 1). Currently, such deaths are coded as X33 ('victim of lightning') in the International Classification of Diseases (ICD), Tenth revision, 1990. Deaths caused indirectly by lightning, such as when someone is killed in a house or factory by a fire started by lightning, are not included in these statistics. Annual reports provide the number, gender and age range of those killed but not the date and detailed circumstances in which someone died. ICD10 sub-codes X33.00 to X33.99 are used by the national statistics agencies to indicate broadly where the fatal incident occurred and the general activity being undertaken at the time but the information is of limited use in this study. For example, X33.09 refers to a 'victim of lightning, home, during unspecified activity', X33.20 a 'victim of lightning, school, other institution and public administrative area, while engaged in sports activity', X33.62 a 'victim of lightning, industrial and construction area, while working for income', and X33.72 a 'victim of lightning, farm, while working for income'. Unfortunately, such codes omit key information needed to better understand the circumstances which put a person at risk of being killed by lightning. Information needed includes the type of sport or leisure activity being undertaken when killed, such as whether they were hill walking, swimming in the sea, fishing or playing golf. A significant number of people are killed when sheltering under a tree which is struck by lightning but the official sub-codes do not provide this information. If killed inside a building, the sub-code offers no insight as to whether it was a substantial building or a small structure (hut, shed, park shelter). If killed indoors, the sub-codes do not state whether the person was using a corded telephone or standing by a window or external door. If killed on a farm, the agricultural activity such as either working outdoors or in a barn remain unknown as does whether, say, they were driving a tractor or riding a horse.

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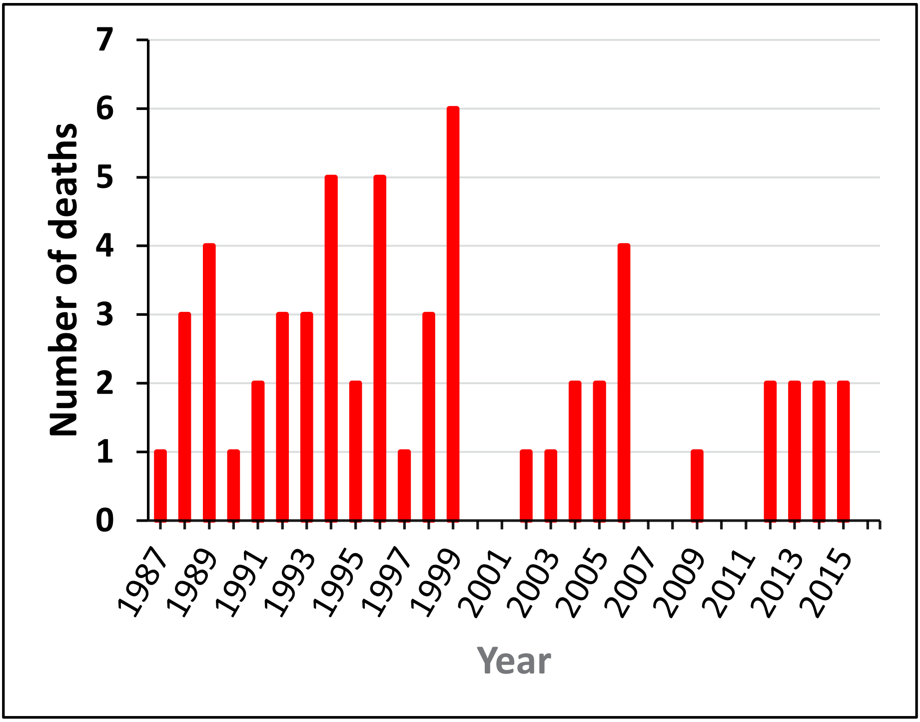
Figure 1. Cloud-to-ground lightning poses a significant risk of injury or death, especially if a person is outdoors. Lightning at Godalming, Surrey, on the night of 15 September 2016 (Copyright: Tim Moxon, www.weatherstudios.com).

To expand the official fatality statistics, TORRO has been compiling details of UK lightning deaths and injuries reported in news media reports and from other sources (e.g. meteorological and medical journal articles; reports send in by TORRO members) since 1993 (Elsom, 1994). This database has been subsequently and retrospectively extended back to the nineteenth century (Elsom, 2015). Annual reports on personal-injury lightning incidents are published in the International Journal of Meteorology (e.g. Elsom and Webb, 2015a; Elsom et al., 2016). One key source for detailed information on UK lightning fatalities has been from observers' reports of the Thunderstorm Census Organisation (TCO) established in 1924. This organisation was taken over by TORRO in 1982 (Elsom and Webb, 2015b) with annual thunderstorm reports being published in the International Journal of Meteorology (e.g. Webb, 2015; Webb, 2016).

The TORRO dataset is cross-matched with the data published by the appropriate official statistics agency using the latter's entry of year of the lightning fatality, gender and age. On occasions, the official entry may report a lightning fatality one calendar year later than it actually happened because the Coroner's Inquest on that person's death had been delayed until the following year. For example, the Northern Ireland Statistics and Research Agency lists a male death, 25-29 years of age, in 2007. However, the TORRO dataset has no known lightning fatalities in Northern Ireland in 2007. Instead the agency's entry actually refers to the death of a 29-year-old off-duty soldier which took place near a stone hut on the top of Slieve Donard, County Down, the highest mountain (850 m) in Northern Ireland and part of the Mourne Mountains, on Saturday 8 April 2006 but the Coroner's Inquest was not held until May 2007. Lucas (2009) also confirms this 2006 fatality was the only known lightning death in Northern Ireland during the period from 1982-2003. The National Office for Statistics in England and Wales lists an entry for the death of a 20-24 year-old man in 2007. This corresponds to the TORRO entry for a lightning death of a 24-year-old man at Warwick on Saturday 22 July 2006. He was struck as he was leaving a Folk Festival, and crossing Castle Bridge, and died six days later in hospital when his life support was turned off because of severe brain damage. The Coroner's Inquest was not held until January 2007 which explains the belated official entry for this lightning death. In four cases, the TORRO dataset lists a known lightning fatality which is not included in the official statistics. However, TORRO's detailed information makes it evident that a fatality in which lightning was the underlying cause did happen in England in 1989, 2006 and 2012, and in Scotland in 1998. For four official national agency entries for England and Wales (two in 1999; one in 2006 and 2013), TORRO does not, as yet, have information but it continues to search for these details. The combined database for lightning deaths in the UK is presented in Figure 2.

Figure 2. Annual number of deaths caused by lightning in the UK in the past 30 years (1987-2016).



ANNUAL NUMBER OF LIGHTNING DEATHS

In the past 30 years, 58 people have been killed by lightning in the UK, that is, on average two people per year. Figure 2 highlights the annual variation during this period and it is evident that, for example, the early half of the period experienced more years with three or more deaths than the latter half of the period when there were even seven years recording zero deaths (2000, 2001, 2007, 2008, 2010, 2011, 2016). The general reduction in the annual number of deaths within this 30-year period reflects a continuation of a long-term downward trend since the mid-nineteenth century as highlighted by Elsom (2015). For example, during the corresponding 30-year period a century ago (1887-1916) there were 553 lightning deaths with an average of 18 deaths per year, much higher than the modern period (Table 1).

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Table 1. Total number and average annual number of UK lightning deaths in 30-year periods: 1987-2016 and 1887-1916.

30-year period	Total number	Annual average	Highest year	Lowest year	% male
1987-2016	58	2	6 (1999)	0 (several years since 2000)	83%
1887-1916	553	18	48 (1895)	8 (1902,1906, 1909)	87%

Note: The number of lightning deaths for the 1887-1916 period above are based on official statistics for England and Wales and from TORRO records for Northern Ireland and Scotland. Official national records for Northern Ireland and Scotland were not compiled for those years. However, TORRO's on-going search for lightning deaths reported in national, regional and local newspapers for the nineteenth and twentieth centuries suggests 30 deaths (and possibly more) occurred in Scotland and Northern Ireland during 1887-1916. This produces a UK total of 553 (523 + 30) deaths and an average of 18.4 deaths per year.

RISK OF BEING KILLED BY LIGHTNING

Lightning has been the underlying cause of death in the UK of 58 people in the past 30 years (1987-2016) or, on average statistically, 1.9 deaths per year. The UK population during that time increased from 56.8 million in 1987 to 65.5 million (provisional estimate) in 2016 and averaged 60.1 million over that period. This indicates the risk of being killed by lightning in any one year is 1.9/60.1 million, that is, 0.03 deaths per million population per year ($M^{-1}yr^{-1}$) or simply one death for every 33 million people (Table 2). For comparison, a century ago, the comparable 30-year period (1887-1916) experienced an average of 18.4 deaths amongst an average UK population of 38.3 million. This indicates the risk of being killed by lightning in any one year a century ago was 18.4/38.3 million or approximately 0.5 $M^{-1}yr^{-1}$, that is, one death in around 2 million people (Table 2).

Table 2. Risk of lightning death in recent and historical 30-year periods in the UK.

30-year period	Annual average deaths	Average annual population	Average number of deaths per million per year ($M^{-1}yr^{-1}$)	Risk of one death per X million (rounded to a million)
1987-2016	1.9	60.1 million	0.03	1 in 33 million
1887-1916	18.4	38.3 million	0.48	1 in 2 million

Note: Refer to the note about annual average lightning deaths below table 1. Also, for the 1887-1916 period, census data gives an average population total of 32.6 million for England and Wales. Average population totals for Northern Ireland and Scotland are estimated at 1.2 million and 4.5 million respectively.

Table 3 presents the UK lightning risk for the most recent ten-year period (2007-2016) of one in 71 million compared with the comparable period a century ago (1907-1916) of one in 2 million. The current annual lightning fatality risk, whether based on the recent 30-year or 10-year period, represents a considerable lessening of the lightning risk compared with a century ago as also shown by Elsom (2015) (Figure 3).

Table 3. Risk of lightning death in recent and historical 10-year periods in the UK.

10-year period	Annual average deaths	Average annual population	Average number of deaths per million per year ($M^{-1}yr^{-1}$)	Risk of one death per X million (rounded to a million)
2007-2016	0.9	63.5 million	0.014	1 in 71 million
1907-1916	17.8	41.4 million	0.5 (0.47)	1 in 2 million

Note: The annual average number of UK lightning deaths and population was obtained following similar assumptions to those explained in the notes below Tables 1 and 2.

Figure 3. Lightning has caused fewer annual deaths since 2000 than in any similar length of period since the nineteenth century. Lightning at Godalming, Surrey, on the night of 15 September 2016 (Copyright: Tim Moxon, www.weatherstudios.com)

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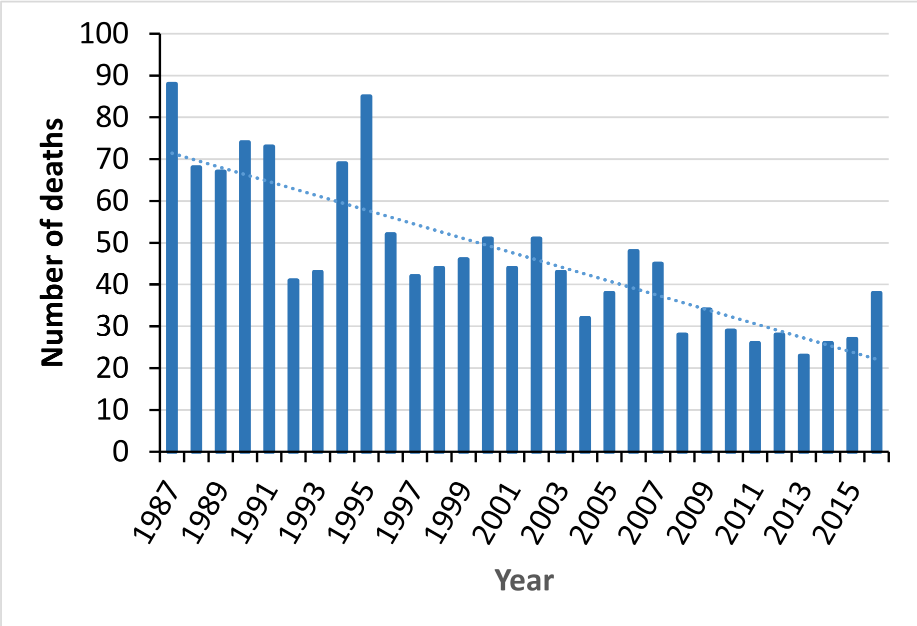
The risk of being killed or injured by lightning is much greater as many more people are injured than die. Elsom and Webb (2014) found the average ratio of the annual number of injuries to deaths in the UK was 14:1 for a recent 25-year study period. A lower ratio of 10:1 was suggested for the USA and some other countries (Holle, 2008). The lower ratio found for these countries probably arises because those analyses included fewer numbers of people who experienced minor, non-burn injuries and who were not treated medically. In contrast, the TORRO National Lightning Incidents Database includes minor injury incidents such as when a person reported, say, being thrown to the ground, suffering temporary paralysis or weakness in one or more limbs, or experiencing a tingling electrical effect as a result of a nearby lightning strike but they did not refer themselves for medical treatment. Using both ratios (10:1 and 14:1) suggests the UK risk of being struck by lightning and experiencing an injury or death for the most recent 10-year period (2007-2016) is 0.9 deaths + 9.0 injuries/63.5 million or 0.9 deaths + 12.6 injuries/63.5 million, that is, an average risk of between 0.16 to 0.21 per $M^{-1}yr^{-1}$ or, more simply, around one person in every 5 to 6 million people.

COMPARING THE ANNUAL NUMBER OF LIGHTNING DEATHS AND LIGHTNING RISK IN THE USA WITH THE UK

Not surprisingly, the number of lightning deaths in the USA is much higher than the UK because it includes areas with considerably higher thunderstorm activity and lightning flash densities (Christian et al., 2003; King, 2003) and a population that is five times that of the UK. The number of lightning deaths has fallen during the past 30 years from 60-80 deaths in the earlier years to 20-40 deaths in the latter years (Figure 4). The average number of annual fatalities was 46.8 deaths in the 30-year period 1987-2016. The mid-year population rose from 242 million in 1987 to 323 million by 2016. Consequently, the annual average risk of being killed by lightning in the USA during that period was 46.8 deaths/284.3 million, that is, 0.165 $M^{-1}yr^{-1}$ or one in 6 million people. Using only the past ten years (2007-2016) the annual average risk of being killed by lightning in the USA was 30.4 deaths/311.9 million, that is, 0.098 $M^{-1}yr^{-1}$ or one in 10 million. In other words, comparing the USA results with those summarised in Tables 2 and 3 for the UK, the chances of being killed by lightning in the USA in recent years is significantly greater than in the UK. However, both the UK and USA currently experience relatively low fatality rates. Low fatality rates are also experienced in Australia, Canada, Japan and throughout Western Europe (Cooper et al., 2016; Holle, 2008, 2016). The most unfavourable (worst) rates are found in countries in Africa and South America where national fatality rates per million people per year exceed 0.6 $M^{-1}yr^{-1}$ (one in 1.7 million) and, in a few cases, may even exceed 5.0 $M^{-1}yr^{-1}$ (one in 200,000 people)

Figure 4. Annual number of lightning deaths in the USA in the past 30 years (1987-2016). A linear trend line has been added.



Note: Data from National Weather Service http://www.lightningsafety.noaa.gov/fatalities.shtml

FACTORS INFLUENCING AN INDIVIDUAL'S RISK OF BEING KILLED BY LIGHTNING

Although the current risk of being killed by lightning In the UK is relatively low compared with other weather-related causes of death (e.g. exposure to excessive natural cold or heat), there are several factors which determine whether individuals are at greater or lesser risk than the national average risk of being killed by lightning:

1. ***Home country.*** England experiences a much higher incidence of thunderstorms and lightning flash densities than Northern Ireland, Scotland and Wales (refer to Figure 1 in Elsom, 2015, and Figure 2 in Webb, 2015 and Webb, 2016). Therefore, not surprisingly, most of the deaths in the UK during the past 30 years occurred in England (81 per cent, that is, 44 out of the 54 deaths with known locations) and few elsewhere: Northern Ireland (1 death), Scotland (6) and Wales (3). The four deaths for which the location is unknown refers to those listed by the Office of National Statistics as 'England and Wales'.

2. ***Activity being undertaken when lightning threatens.*** Activities being undertaken at higher elevations (hills, mountains, moors, cliffs) will likely increase the risk of being struck compared with activities undertaken at lower elevations. Activities being undertaken in wide-open spaces (farm and sports fields, open water, beaches), where a person may be the highest point around, are at greater risk than those undertaken in relatively enclosed areas such as in towns and cities. In urban areas, there are many high buildings, street light poles and television aerials which are more likely to be struck by lightning than someone in a street or garden.

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3. ***Actions taken or not taken when lightning threatens.*** Getting to a safe shelter when lightning threatens may save a person's life although, too often, those killed or injured may have either failed to do so or did not do so quickly enough. Being on a hill or mountain when lightning threatens means someone is a very long way from a safe shelter (substantial building or metal-topped, enclosed vehicle). In contrast, being in an urban area means there are many nearby substantial buildings in which to shelter. Unfortunately, some people wait too long before seeking safety and are struck a short distance away from safety. Contributing to a slow response to the lightning threat may be background noise (urban noise; blustery winds; heavy rain) which limits an individual's ability to hear thunder. Nearby hills, trees or buildings may block a person's view of a developing thunderstorm. Some people do take prompt action when lightning threatens but that action is wrong and potentially fatal such as when seeking shelter under a tree or in a hut, shed, outhouse or unfinished building which lack adequate electrical earthing if lightning strikes this type of building (Figure 5).

Figure 5. A person's decision to discontinue an activity when lightning threatens is often left too late and a safe shelter (substantial, electrically-earthed building or a metal-topped enclosed motor vehicle) cannot be reached in time. Lightning at Godalming, Surrey, on the night of 15 September 2016 (Copyright: Tim Moxon, www.weatherstudios.com).

4. ***Whether resuscitation is attempted.*** The most common cause of death due to lightning is cardiopulmonary arrest. Indeed, someone is highly unlikely to die unless cardiopulmonary arrest is sustained (Cooper et al., 2016). Prompt cardiopulmonary resuscitation (CPR) may prevent this from happening. Prior to the 1960s, few bystanders knew how to administer CPR. Also the time taken for paramedics to arrive with a defibrillator and other advanced cardiac life support was too long, especially if the incident happened in a remote area. TORRO's records reveal that, during the past 30 years, 20 lightning casualties are known to have been resuscitated and, together with follow-up hospital treatment, survived. A century ago these people would have very likely died.

5. ***Gender?*** Gender is not an underlying reason for increasing or decreasing the risk of being killed. Instead it is the type of activity being undertaken when lightning threatens in an area that is more important. More men than women tend to participate in activities considered high-risk of being struck by lightning. In a specific area, high elevations tend to be struck more by lightning than lower elevations so participating in hill and mountain walking, camping, climbing, fell running and mountain biking is a serious risk if thunderstorms develop. More men than women participate in these activities. Wide, open areas at lower elevations such as golf courses and sports fields (pitches), mean that a participant is the highest point in the vicinity to which the stepped leader of lightning can attach, and there is a higher proportion of men than women participating in these types of sports. The gender distribution of female/male participants in many sports is changing so a significantly higher female percentage of lightning deaths may occur in the future.

TYPES OF ACTIVITIES BEING UNDERTAKEN AT THE TIME OF DEATH

Of the 58 lightning deaths in the past 30 years, the activity being undertaken by the deceased at the time they were struck was known for 54 people. This sample of lightning deaths provides a vital insight into the range of activities being undertaken by people when they were struck and killed by lightning in the past few decades. Percentages are employed in this analysis for convenience but, where appropriate, absolute numbers are stated too.

Three broad groups of activities can be identified, as employed by Elsom (2015) for the UK and Jensenius (2016) for the USA. These are: 'work' (indoors and outdoors), 'involved in the daily routine (indoors and outdoors), including travelling to and from home to work or school' and 'participating in leisure, recreation and sports activities'. The activity being undertaken when killed refers to the activity which placed that person at risk. When struck by lightning while 'walking the dog', this could be categorised as being involved in the daily routine or a leisure activity. A distinction is made in this analysis by categorising this activity as 'daily routine' if it is undertaken near the home, that is, in the local area (in nearby streets, a park or common) but as a leisure activity if undertaken at more distant locations such as on hills, cliffs, moors and cliff-tops. Four deaths, two in each category, were of people who were killed while walking their dog. When exploring fatalities within each of the three broad categories, the activity which placed them at risk also determines the sub-category group. For example, if a person had been playing football or fishing but was struck by lightning as they ran for shelter, the fatality was placed in the sub-category of 'participating in the sport of football or fishing' respectively.

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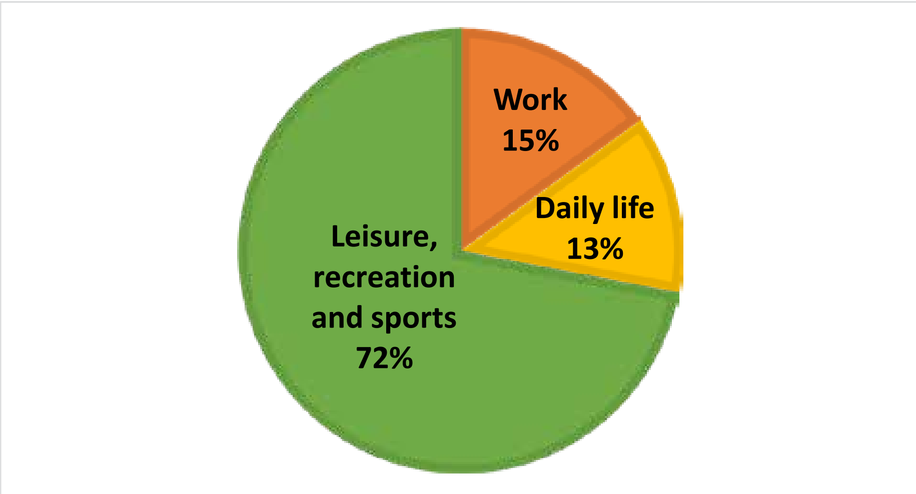
As Figure 6 highlights, 'work' activities accounted for 15 per cent (8 deaths) of all known deaths, undertaking 'daily routine (daily life)' 13 per cent (7 deaths) and participating in 'leisure, recreation and sports activities' 72 per cent (39 deaths). In absolute terms, the 8 deaths 'at work' were in agriculture (4), construction (2), fish farming (1) and military/armed forces (1). Apart from one death in April 2012 near Crewe, Cheshire, of a 41-year-old bricklayer struck outside on a building site while standing and drinking tea, the other 'work' deaths took place in 1996 or earlier. This may suggest a growing awareness over time of the threat of lightning whilst at work. The seven deaths in the 'daily routine' category all occurred when the victims were walking to or from home to a school, work or the shops or were walking the dog in the local area.

Figure 6. Lightning fatalities by activity in the past 30 years (1987-2016) in the UK.



The 39 fatalities in the 'leisure, recreation and sports activities' category occurred while walking for leisure (20), fishing (4), playing golf (4), playing cricket (3), playing football (3) playing rugby (1), undertaking a water-related activity (kayaking) (1), children playing (1), holidaying in a caravan park (1), and flying a model aircraft on a disused airfield (1). More than half of those killed while engaged in a sports activity (9 out of 16) were continuing their activity when struck while the others were either seeking shelter or had reached shelter. Unfortunately, amongst the latter group, the shelter chosen was often a bad choice, being a tree which was subsequently struck and they were killed when the lightning passed down the tree trunk and side flashed (splashed) to the individual(s) sheltering from the heavy rain beneath.

For example, on 27 June 2009 at Small Heath Park, Birmingham, West Midlands, a group of teenagers had their cricket match interrupted by a thunderstorm. They sought shelter from the heavy rain under a nearby tree which was then struck. Five boys suffered minor injuries, one suffering convulsions, and a 16-year-old suffered serious burns and cardiac arrest but was resuscitated. Unfortunately, he died in hospital three days later.

During the past 10-15 years, most golf courses have begun providing a warning when thunderstorms develop (sounding of a klaxon) to tell players to discontinue playing immediately and head for the Clubhouse. Unfortunately, no klaxon was sounded at a Newbury golf course on 28 June 2005 as the manager had left and even though two golfers had decided to stop play and seek the safety of the Clubhouse, they were struck on their way and one was killed.

Ten of the 20 leisure walking fatalities occurred on hills, mountains or cliff tops – all were men. This highlights that walking at exposed, high elevation locations, often distant from safe refuges, contributed to one fifth (22 per cent) of all UK deaths in the past three decades for which the activity being undertaken by the deceased at the time they were struck was known (54 deaths). It is clearly important for those engaged in this activity to be aware of the lightning safety guidance outlined previously by Elsom et al. (2016) for hill and mountain walkers. Hill walkers need to pay particular attention to weather forecasts and postpone the activity if thunderstorms are forecast. Unfortunately, some people lead busy lives and are very reluctant to alter their plans and so put themselves, friends and family at risk of being struck by lightning.

NOTES ON DAYS WITH FATALITIES ASSOCIATED WITH LEISURE ACTIVITIES

Regarding awareness of the lightning risk, an investigation has been made of the synoptic and weather situation on days when thunderstorms developed and lightning resulted in deaths amongst people undertaking leisure activities, specifically when they were walking on hills, mountains and cliff tops and walking at lower elevations including parks, a canal bank and on the side of a Scottish loch. During the 30 year period there were 19 days in which people engaged in these activities died as a result of injuries directly related to lightning.

Lamb's Classification of weather types (Climate Research Unit, University of East Anglia) is a convenient way of expressing the airflow – direction of the overall isobaric pattern - over the British Isles based on the grid 50°N to 60°N and 10°W to 2°E. A variety of weather types occurred on days when fatal lightning incidents occurred. Southerly or southeasterly types were noted for five of the days; eight occasions were classified as Cyclonic (including one day each of the CSE, CNW and CW type); five days were Anticyclonic; and one day was Northerly. A more relevant classification for the current analysis is to consider the synoptic situation and airflow around the time (and location) of each of the fatality incidents. Four synoptic and airflow scenarios were identified (Figure 7). Only four of the days occurred in the classic or modified Spanish Plume situation (Lewis and Gray 2010; Met Office, 2017), the major scenario for widespread severe thunderstorms (scenario 1). Three other fatal lightning incident days involved warm, rather stagnant air in slack weather situations (Cols or shallow depressions) where thunderstorms are especially favoured along convergence zones like sea breezes (scenario 2). The remaining 12 days featured air masses of polar maritime origin, albeit sometimes with a long 'fetch'. Six of these were in showery situations in cyclonic westerly or northwesterly set-ups with one occasion being in winter (scenario 3), and six were linked to returning maritime polar air with a cyclonic curvature, arriving from between southeast and southwest (scenario 4). Scenario 4 was present on the two occasions with deaths from more than one incident: 1 May 1988 (three separate incidents resulted in the deaths of three walkers, two in Cumbria and one in Shropshire) and 5 July 2015 (two incidents resulted in the 'simultaneous' deaths of two hill walkers on peaks 1.7 km apart on the Brecon Beacons, South Wales, as explored by Elsom et al., 2016).

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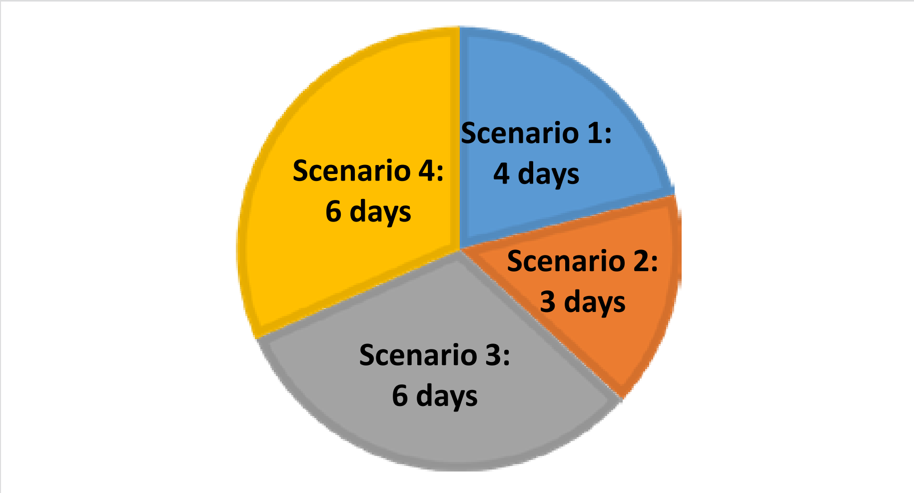
Figure 7. The synoptic and airflow situations on days when people participating in leisure walking were struck and killed by lightning in the past 30 years (1987-2016) in the UK.



Scenario 1. Classic or modified Spanish Plume situations.	Scenario 2. Warm, rather stagnant air in slack weather situations (COLS or shallow depressions).
Scenario 3. Showery situations in cyclonic westerly or northwesterly set-ups	Scenario 4. Returning maritime polar air with a cyclonic curvature, arriving from between southeast and southwest.

During the 'warm season', days with polar maritime air often start with sunny, relatively cool, fresh mornings; visibility is excellent and the prospect is initially inviting for leisure walkers, including those interested in weather photography. Moreover, forecasts will probably not give the risk of thunder such a high profile as on days of the 'warm plume' scenario; a typical forecast might be "showers developing, some heavy with a chance of hail and thunder". The initial thundery showers may have just occasional discharges which means a possible warning of thunder rumbling in the distance may be absent.

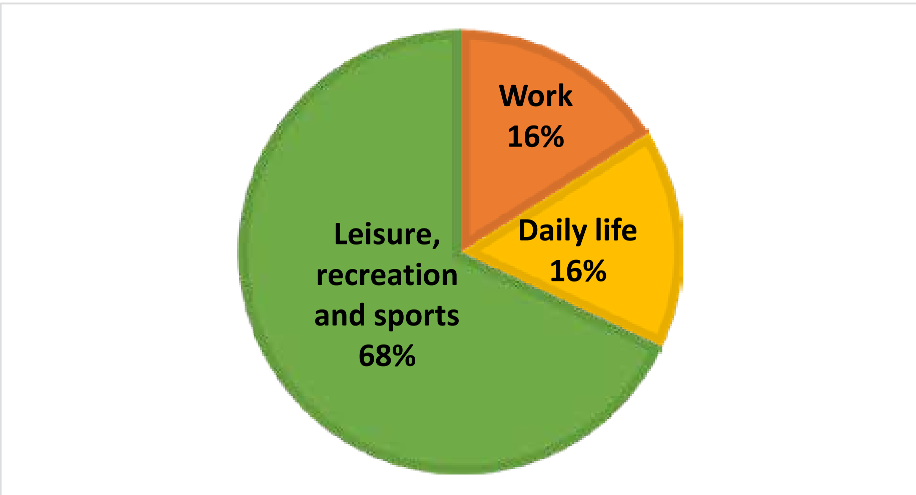
INDOOR DEATHS?

Although people have been injured by lightning indoors in the past 30 years in substantial, electrically earthed buildings, there have been no deaths (Elsom and Webb, 2014). This contrasts markedly with a century ago when, for example, in the decade of the 1900s (1900-1909), 24 per cent of all deaths occurred indoors (Elsom, 2015). The reason why people were vulnerable when lightning struck substantial buildings in the 1900s and in earlier periods was because these buildings lacked the electricity, telephone and plumbing circuits that today provide routes to conduct the electric current of the lightning from the point of contact to the ground. Consequently, in modern buildings the current passes around or within the structural frame of a building and through its walls before eventually earthing in the ground. Unless a person is in contact with or close to these circuits they are unlikely to experience a fatal current. The walls may be damaged as cables are heated virtually instantaneously to very high temperatures resulting in burning and explosive damage. Surge protectors fitted to electrical appliances and computers minimise the electrical current to which a user may be exposed. Lightning injuries continue to happen indoors but no deaths inside well-grounded, substantial buildings are known for the past five or six decades in the UK. Unfortunately, small structures such as huts, sheds and park shelters are not usually well-grounded electrically so fatalities may continue to happen inside them (Elsom, 2015).

COMPARISON WITH THE USA

There were 313 people killed by lightning in the USA for a recent ten-year period (2006-2015). Detailed information was known for 297 deaths (95 per cent). Jensenius (2016) analysed these 297 deaths and found that work-related activities accounted for 16 per cent of the deaths (47 out of 297), the daily or weekly routine for 16 per cent (49 out of 297), and leisure and sports activities for 68 per cent (201 out of 297). These percentages, presented in Figure 8, are broadly similar to the UK findings in this paper (Figure 6) which are based on a much smaller number of deaths for the past 30 years.

Figure 8. Lightning fatalities by activity in the past 10 years (2006-2015) in the USA.



GENDER OF FATALITIES

Figure 9 highlights that males accounted for 83% of all lightning deaths in the UK in the past 30 years. This is similar to the USA situation as Jensenius (2016) found that males accounted for 79 per cent of all the lightning fatalities in the ten-year period (2006-2015). Gender percentages have not changed significantly in the UK during the past century or so. For example, during the corresponding 30-year period a century ago (1887-1916), males accounted for 87 per cent per cent of all known lightning deaths (Table 1). The high percentage of male deaths reflect the higher proportion of male participation in outdoor work-related activities (construction, farming, military) and specific outdoor leisure activities (hill and mountain walking) and sports activities (cricket, fishing, football and rugby). The ten female lightning deaths occurred in all three of the broad categories of activities but half were killed while 'walking for leisure' in their local area (in the 'Daily

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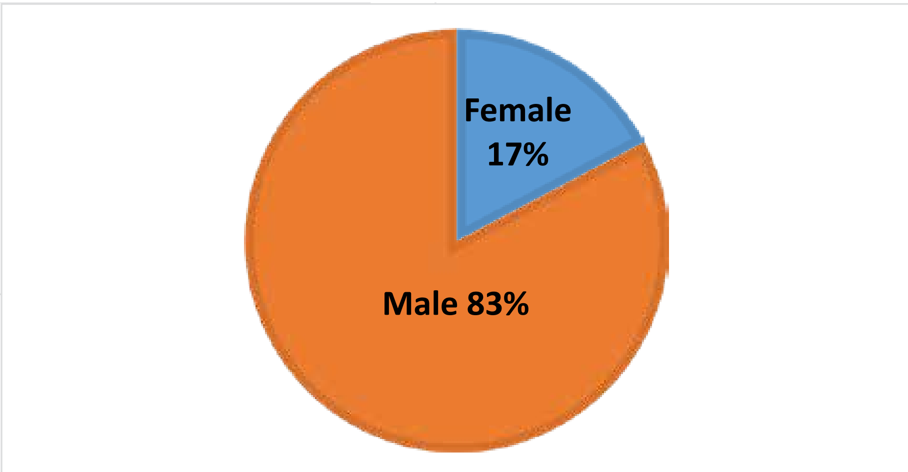
life' broad activity category) on a weekday and none at more remote and high elevation locations (hills, mountains, moors or cliff-tops) where twelve men lost their lives, with eight of the twelve deaths taking place on a Sunday.

Jensenius (2016) raises the question as to whether there are behavioural differences between men and women regarding attitude to the lightning risk and whether this, and not simply the types of lightning-vulnerable activities that more men than women undertake, contributes to the higher male percentage of lightning deaths. Possible behavioural differences suggested include men being less aware of the lightning risk, being less willing to be inconvenienced by the threat of lightning (by postponing a planned activity) and being more likely to ignore the risk until the threat is so imminent that there is little time left to seek safe shelter. An unwillingness to wait at least 30 minutes after the last lightning or thunder before leaving a safe shelter to return outdoors may be another possibility. This issue requires further research.

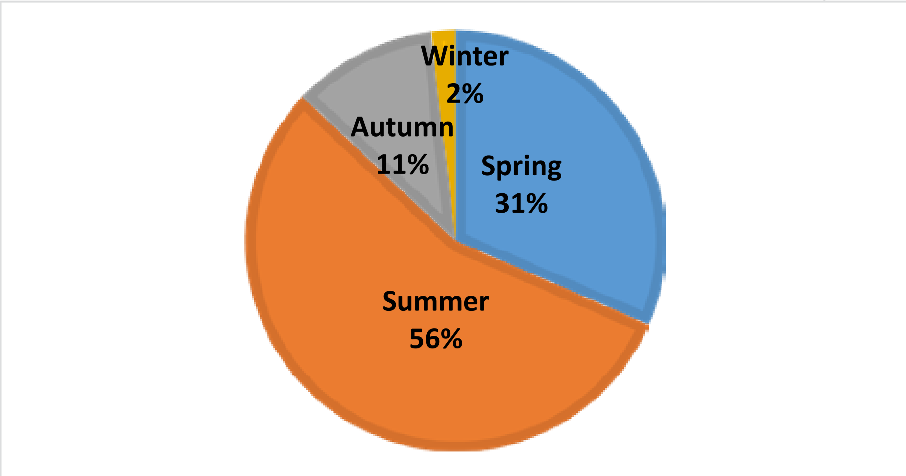
Figure 9. Gender of lightning fatalities in the past 30 years (1987-2016) in the UK.



TEMPORAL VARIATION OF LIGHTNING DEATHS

Not surprisingly, given the seasonal distribution of thunderstorms, it is the spring and summer that accounted for 87 per cent of all lightning fatalities (Figure 10). More specifically, the four months of May (13 deaths), June (8 deaths), July (9 deaths) and August (13 deaths) were responsible for 80% of all lightning deaths. These are also the months when people spend more time outdoors and participate in outdoor leisure, recreation and sports activities. May is commonly the month when the first major thunderstorms of the year occur in the UK. Many people will be spending time outdoors in May enjoying the spring warmth, perhaps the first warm period of the year since winter, and may not realise that thunderstorms can develop rapidly on such days and pose a lightning risk.

Figure 10. Lightning fatalities by season in the past 30 years (1987-2016) in the UK.



Most lightning deaths occurred during the late afternoon or early evening, a time when thunderstorms are more frequent and more people are outdoors. Fewer people are killed during thunderstorms at night as most people are indoors and relatively safe from a lightning strike compared to being outdoors (Figure 11). Unfortunately, a 22-year-old man who stepped outside his holiday caravan at 0130 UTC during a thunderstorm at Billing, Northamptonshire, on 8 August 1992, was struck by lightning and killed.

Figure 11. Fewer people are killed at night by lightning as most people are indoors and relatively safe from a lightning strike compared to those outdoors. Night-time lightning on 4 July 2015 Bury St Edmunds, Suffolk (copyright: Andrew Scott).

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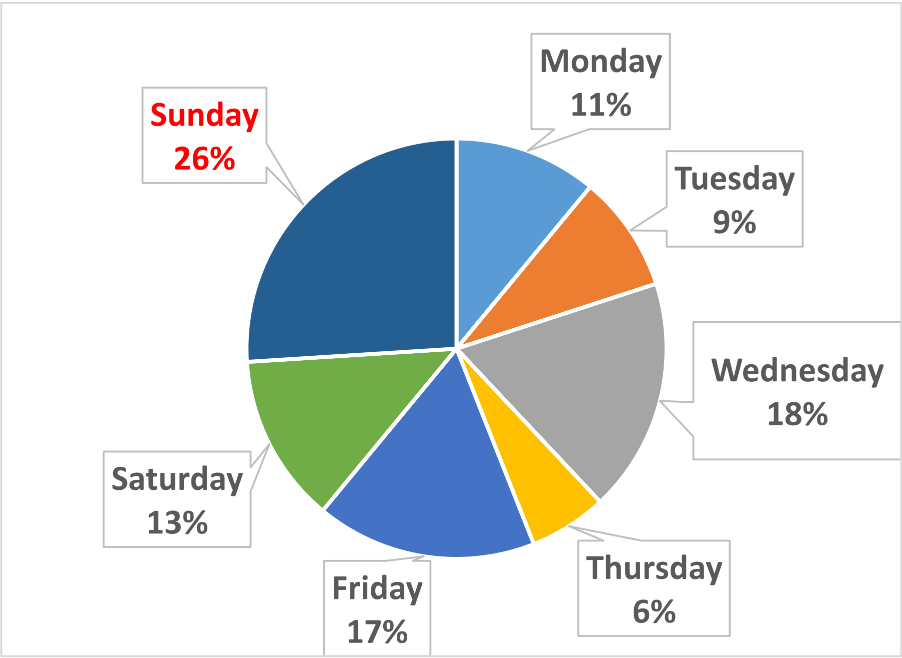
Although lightning deaths occurred on all days of the week, Sundays gave rise to one quarter of all known deaths (26 per cent or 14 out of 54 deaths for which the day is known) as shown in Figure 12. This reflects that Sunday is a day when larger numbers of people have the time to participate in leisure and recreation activities which may put themselves at risk, such as hill walking. All the male and female deaths in the 'work' activity category occurred on weekdays. All female deaths happened on weekdays.

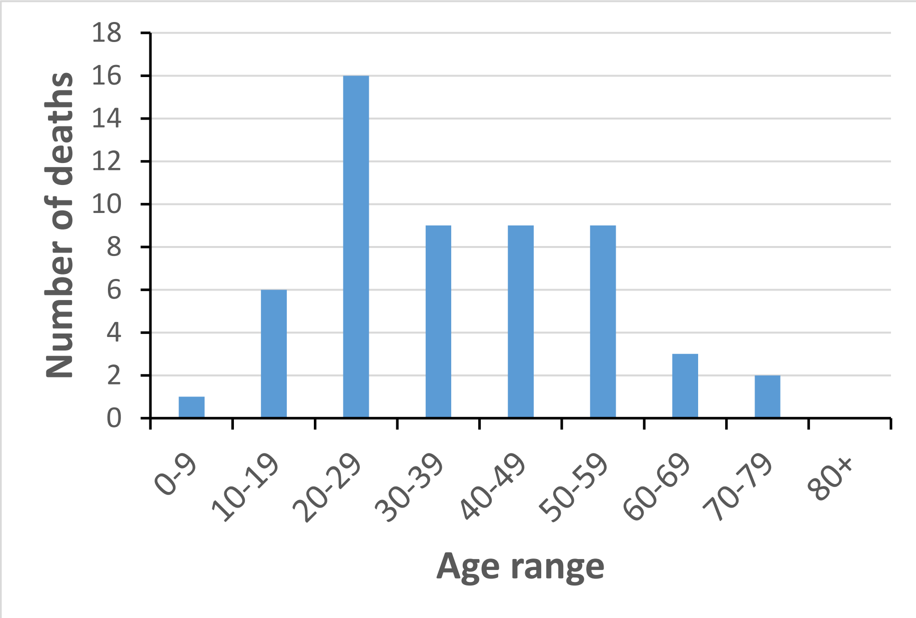
Figure 12. Lightning fatalities by day-of-the-week in the past 30 years (1987-2016) in the UK.



AGE OF LIGHTNING FATALITIES

The youngest death was a two-year-old girl on 7 September 1994 who was with her mother while she was picking potatoes in a wide open field near Faversham, Kent, when they were both struck by lightning. Her mother was only slightly injured. The oldest person killed was a 75-year-old retired miner who was struck by lightning whilst walking near his home on a footpath in Ammanford, Dyfed, Wales, on 24 May 1989. The highest number of deaths occurred amongst the 20-29 year-age-range (Figure 13). Their deaths were associated with participating in sports activities (cricket, football, golf, fishing), undertaking leisure and recreation activities (walking) and working (farmer, fish-farm worker, house repairer). A larger sample size would be needed to explore age-range differences more fully.

Figure 13. Lightning fatalities by age group in the past 30 years (1987-2016) in the UK.



CONCLUSION

The details about lightning deaths in the past 30 years provide an important insight into the risk that lightning poses to people in the UK. Participating in the broad group of 'leisure, recreation and sports activities' poses the greatest risk. Leisure walking on hills, mountains and cliff-tops (12 deaths) together with participating in outdoor sports activities, especially cricket, fishing, football, golf, rugby and watersports (16 deaths) gave rise to around half (52 per cent or 28 of 54 deaths for which activities were known) of all UK deaths in the past three decades. Ensuring all people understand that lightning in their vicinity will always pose a dangerous risk (unless they are indoors in a substantial electrically-grounded building or in a metal-topped enclosed motor vehicle) will be vital if fatalities are to be avoided in the future. Particular efforts need to be directed toward hill and mountain walkers and outdoor sports participants to ensure they reschedule or promptly curtail their activity when thunderstorms are forecast or develop respectively (Elsom et al., 2016). Moreover, the decision to discontinue an activity when lightning threatens needs to be taken with sufficient time to reach a safe shelter.

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THE WEATHER IN DURHAM 2016

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A warm year, a little wetter than average but lacking in sunshine

January was a mild month: it was equal 24th highest mean air temperature, warmer than last year but 2014 was warmer. There was the equal 39th highest mean maximum since 1900 and the 7th highest mean minimum. The 24th was the warmest January day since 2003. There was the lowest number of ground frosts since 2008. There were 5 days with a maximum above 10°C but this is nowhere near the record of 17 in 1916. There were 10 nights where the minimum was above 5°C; only 1898 and 1916 have had more (11). It was a very wet month, almost twice the January average; it was the third wettest January since 1850, the wettest January since the record-breaking January 1948 (192.1 mm). The 3-month total to the end of January was the 10th wettest 3-month period since 1850 (n=1991) and the wettest three months since autumn 2000. Whilst January 2015 was record-breaking for sunshine hours, 2016 was by stark contrast the 12th lowest total, but still well above the desperate total of 7.6 hours in 1996, the last time a January was less sunny in Durham.

February was equal 68th warmest on record, exactly the same as last year. Both mean maximum and mean minimum were above average, the former more so. Like the previous four Februaries, rainfall was below average. Even so, long-period totals remained well above average. Not surprisingly, given the lower than expected rainfall, the hours of bright sunshine were above average. It was the 3rd equal warmest winter on record (5.6°C, with 2007), beaten only by 1998 (5.7°C) and 1989 (6.3°C). Despite below-average rainfall in February, it was the 6th wettest **winter** on record since 1850-51, the highest total since 1979. Winter sunshine was very close to average.

Although **March** did not feel particularly mild, it was in fact well above average temperature, the 55th equal warmest in 168 years, and there were fewer ground frosts than usual. Rainfall was just a little above average but the long-period totals remained well above average. There was less sunshine than usual but only two days with no recorded sunshine at all. Shallow soil temperatures were now above 6°C so spring growth should have started, but **April** was a disappointing month. Mean air temperature was well below average, 49th equal lowest since 1850, the coldest April since 1989. It was the first below-average month since the previous July. It was the 17th wettest April in 167 years but only the wettest since the very wet April of 2012 (134.4mm). Period totals for the last six and twelve month periods remained well above average. As expected, sunshine was a little below average. Following a disappointing April, **May** was a warm month, equal 29th warmest in 167 years. Minimum temperatures in particular were well above average; the mean minimum was equal 12th warmest since 1900. The best of the

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	JAN	FEB	MAR	APR	MAY	JUN
Mean air temperature (°C)	4.7	4.2	5.8	6.6	11.1	13.2
Difference from average	1.7	1.0	0.8	-0.4	1.2	0.2
Mean maximum temperature (°C)	6.8	7.3	9.1	10.2	15.1	17.0
Mean minimum temperature (°C)	2.6	1.0	2.4	3.0	7.0	9.3
Absolute maximum temperature (°C)	14.1	12.0	13.0	16.9	22.2	25.6
Absolute minimum temperature (°C)	-2.6	-3.1	-1.8	-1.2	2.8	5.4
Number of ground frosts	13	18	11	12	0	0
Rainfall total (mm)	116.6	28.0	58.0	81.4	41.7	49.2
Difference from average	57.2	-13.6	6.8	34.1	-10.5	-2.6
Rainfall %	196	67	113	172	80	95
Highest daily rainfall (mm)	28.4	6.8	15.2	11.2	11.8	8.6
Number of rain days	23	13	13	20	9	14
Sunshine hours	32.3	86.3	87.1	119.4	137.6	106.2
Maximum daily sunshine	7.3	7.4	8.5	4.1	11.5	11.3

temperatures came early in the month with a welcome maximum of 22.2°C on 8th. Rainfall was below average, but all long-period totals remained above average, the 6-month and 12-month totals especially. Despite lower than average rainfall, hours of bright sunshine were below average too, by nearly an hour per day, reflecting the predominance of cloudy conditions with a generally easterly air flow off the North Sea.

June was another disappointing month: average temperature and average rainfall and much less sunshine than usual. Daytime temperatures were below average but the reverse was true at night, no doubt because of the generally cloudy skies. It was not a wet month and half the days were dry. Sunshine was well below average, the 8th least sunny June on record since 1882. There were five days with no sun at all. There were 2 hours less sunshine per day than normal, but it was still much better than 2012 when Durham only received 72 hours of bright sunshine in June. **July** experienced above-average temperatures, at night especially. There were nine days with maxima above 20°C, from the 16th to the 24th; with a maximum of 28.9°C on the 19th. For an unknown reason, the concrete thermometer failed to operate for four days but when it started to work again, the concrete surface temperature was 43.8°C (11 a.m. on the 19th)! Rainfall was below average but so too was sunshine. Nevertheless, despite the lack of bright sunshine, overall it was a very pleasant summery month! **August** was very similar in

JUL	AUG	SEP	OCT	NOV	DEC	**YEAR**	
15.8	15.7	14.9	10.1	4.9	6.1	**9.4**	Mean air temperature (°C)
0.9	1.0	2.2	0.3	-0.8	2.2	**0.8**	Difference from average
19.6	19.6	18.7	13.3	7.8	8.4	**12.7**	Mean maximum temperature (°C)
12.0	11.7	11.0	6.9	2.0	3.7	**6.1**	Mean minimum temperature (°C)
28.9	24.3	26.8	17.9	15.2	14.8	**28.9**	Absolute maximum temperature (°C)
6.2	7.0	6.2	2.0	-3.2	-3.1	**-3.2**	Absolute minimum temperature (°C)
0	0	0	1	8	8	**71**	Number of ground frosts
35.2	69.8	44.2	50.4	87.8	36.6	**698.9**	Rainfall total (mm)
-16.4	2.7	-11.4	-2.2	25.8	-20.9	**49.9**	Difference from average
68	104	79	96	142	64	**10**	Rainfall %
6.6	16.8	10	6.6	31.4	10.4	**31.4**	Highest daily rainfall
14	14	10	18	16	12	**176**	Number of rain days
114.1	142.8	112.1	72.8	81.5	68	**1160.2**	Sunshine hours
10.4	9.7	9	7.2	8.6	10.7	**11.5**	Maximum daily sunshine

terms of temperature to July and, whilst not exceptionally warm, it was warmer than the previous two Augusts. Overall, it was the 18th warmest August in 167 years. Rainfall was just over average and sunshine hours just below average. The 3-month and 6-month cumulative rainfall totals were close to average but the 12-month total remained well above average. The wettest day was Bank Holiday Sunday with a total of 16.8 mm. Even though there was less sunshine than normal, it was the sunniest August since 2007.

For the **summer** as a whole, it was the 29th equal warmest in 167 years (14.9°C), 0.7°C warmer than the 1961-1990 average but by no means exceptional. The warmest summer day was 19th July when a maximum of 28.9°C was recorded. Summer rainfall (152.4 mm) was just below average, with only August being (slightly) above average. Even so, it was the driest summer at Durham since 2006. In terms of sunshine, it was a dull summer, the 9th dullest on record since 1882 (367 hours). Even so, three summers since 2000 have had less bright sunshine, the most recent in 2012. According to the Davis index of summer weather (which combines temperature, rainfall and sunshine), summer 2016 was just better than average, ranking 59th best in 136 years: pleasant but unexceptional.

September was an exceptionally warm month, the 4th warmest September on record since 1850, beaten only in 1865, 1949 and 2006 (which holds the record – 16.0°C). The mean maximum temperature was the 12th highest on record and the mean minimum temperature was the 3rd highest (beaten only by 2006 and 1949). The maximum temperature exceeded 20°C on seven days, whilst the mean minimum was above 10°C on a remarkable 19 days (26 in 2006!). The maximum on the 13th was the 12th - equal warmest September day since 1850, the warmest September day since 1959; 1st September 1906 holds the record – 30.0°C! Both rainfall and sunshine were slightly below average.

October was dominated by easterlies for much of the month, which gave a damp, dull feel to the weather. Even so, temperatures were above average, minima rather more so than maxima. The mean air temperature was only 0.3°C above average but nevertheless in the top quartile, equal 33rd warmest. Of the 32 warmer Octobers in Durham since 1850, eight have been this century. The rainfall total was just below average, but clearly the accumulation of many small events, the wettest day having a total of only 6.6 mm. Sunshine was again below average with a disappointing average of only 2.5 hours per day.

After the very mild **November** in 2015, this November was the complete opposite, equal 41st coldest in 167 years and the coldest since 2010. There were a couple of very mild days in the middle of the month, with maxima of 14.8°C (14th) and 15.2 °C (15th), but overall, the maximum only exceeded 10°C on five days. Notwithstanding the generally disappointing temperatures, there were only eight ground frosts, a sign of generally cloudy conditions at night under an often north-easterly air flow. As last year, November had well above average rainfall, this year being the 35th highest November total since 1850 (but lower than the 100.8 mm total in 2015). There were 12 rain days but only one day with a total above 10 mm. There was torrential rain on the evening of the 21st, with the hour ending 2000 GMT recording 9.6 mm. [This was not Storm Angus, but its unnamed partner which followed immediately afterwards.] Whilst this was indeed a remarkable rainfall intensity for Durham, investigation of hourly rainfall data since 2000 showed this was "only" the 21st highest hourly total in 16 years (This record has some gaps; n=157800). The highest recorded hourly total at Durham was on 19th June, 2005 when 21 mm fell in an hour (My report for June 2005 indicates the rain fell in about 40 minutes, in fact). Notwithstanding the high rainfall, there was more bright sunshine than normal, the sunniest November since 2005 and the 12th sunniest since 1882.

December was very mild, but even so, rather cooler than 2015's record-breaker. The mean air temperature was the 12th warmest since 1850. The mean maximum was 12th equal highest and the mean minimum the 6th highest, both since 1900. There was a warmer day last December, but other than that, the maximum of 14.8°C on the 7th was the warmest December day since 2001. December was a dry month, with only two thirds of the normal amount of rain. Not surprisingly therefore, December was a sunny month, the 15th sunniest December since 1882.

2016 was the 17th warmest year (9.4°C) at Durham since 1850, 0.1°C warmer than last year. Of the 16 warmer years, nine have been since 2000; in a stationary series, only two would be expected. Only two months fell below the 1961-1990 average temperature:

April and November. Whilst the decadal running mean for annual temperature has fallen slightly from a peak in 2002 (9.7°C), it remains higher than at any stage before 1998. As a result the number of ground frosts was well below average, the 3rd equal lowest total since 1931 (beaten only in 2000 and 2014). The annual rainfall total (698.9 mm) was 49.9 mm above average but this is not an exceptional total, ranking 58th highest in 168 years. It was a dull year (1160.2 hours), only 89% of the normal amount of sunshine, the 10th least sunny year since 1882.

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The programme is available on the TORRO website www.torro.org.uk and the forum.

We are pleased to announce the conference will, once again, be free of charge to all.

To register for the conference please email through to **membership@torro.org.uk**

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