Remember, remember the fifth of November: was that thunder I heard or not?

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> *1842 it was in dissolving embryo: but it is true, as General Sabine has said, that it would not have flourished but for my exertions. I maintained it against the strong opposition of many influential members of the British Association (& particularly of one…). The system now pursued at Kew is precisely that which I long since in a document, received by a committee, strenuously advocated. For the constantly kind… & powerfull [sic] support of Sir John Herschell [sic] Bar^{t} and several other gentlemen I shall ever feel grateful (Ronalds, 1860).*

Working always in an honorary capacity, Ronalds set up the observatory, in part with his own funds and equipment, and moulded its successful mission. His belief in Kew remained steady when others were wavering or, worse, undermining his efforts. Critically, it was the excellence of his instruments and observations that brought numerous supporters to the institution, and they later used their influence to promote its aims and fight the necessary political battles. Today's hindsight confirms that Ronalds deserves considerable credit for Kew's early survival and later evolution into one of the most important meteorological and geomagnetic observatories in the world. His contributions in establishing Kew's reputation and in facilitating the development of systematic regional- and global-scale meteorology have been underrepresented in science history.

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References

Athenæum. 1845. p 639.

BAAS. 1843–1872. Reports of the British Association for the Advancement of Science. http://www.biodiversitylibrary.org/bibliography/2276#/summary (accessed 1 December 2015).

Collen H. 1846. On the application of the photographic camera to meteorological registration. *Philos. Mag. Ser. 3* **XXVIII**: 73–75.

Galvin JFP. 2003. Kew Observatory. *Weather* **58**: 478–484.

Middleton WEK. 1964. *The History of the Barometer*. Johns Hopkins: Baltimore, MD.

Ronalds F. 1845–1852. *Annual report concerning the observatory of the British Association at Kew*. Reports of the British Association for the Advancement of Science.

Ronalds F. 1847. Experiment made at the Kew Observatory on a new kite-apparatus for meteorological observations, or other purposes. *Philos. Mag. Ser. 3* **XXXI**: 191–192; reprinted 1896: The use of the kite in meteorology. *Monthly Weather Review* **24**: 416–417.

Ronalds F. 1855. *Descriptions de Quelques Instruments Météorologiques et Magnétiques*. Printed privately.

Ronalds F. 1860. Autobiographical Letter, UCL Special Collections, Ronalds Papers, GB 0103 MS ADD 206.

Ronalds BF. 2016. *Sir Francis Ronalds: Father of the Electric Telegraph*. Imperial College Press: London, UK.

Scott RH. 1885. The history of the Kew Observatory. *Proc. R. Soc. London* **39**: 37–86.

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Remember, remember the fifth of November: Was that thunder I heard or not?

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Introduction

The only long-term observations of thunderstorm activity, extending back more than 100 years, are 'thunder days,' wherein an observer records 1 or a 0 depending on whether or not (they think) they have heard thunder that day (e.g. Brooks, 1925; Changnon, 1985; Kitagawa, 1989). Despite the low dynamic range (e.g. storms with 1 or 1000 lightning strokes will both simply register a 1 in thunder days) and the inherent subjectivity of such measurements, they are invaluable for long-term studies of thunderstorm occurrence, which could vary as a result of global warming (Romps *et al.*, 2014) or even changes in the space environment (Stringfellow, 1974; Owens *et al.*, 2014).

Thunder day observations are potentially susceptible to false positives, such as vehicle noise or natural/anthropogenic explosions being wrongly attributed to thunder (e.g. Rampino, 1989). Thus, increasing urbanisation and industrialisation may result in a long-term change in the noise level and hence bias in the data. On shorter timescales, 'Bonfire Night' (or 'Guy Fawkes Night') on 5 November in the UK, as well as New Year's Eve, are obvious candidates for false-positive thunder identification.

Data and analysis

Thunder day records produced by professional observers at Met Office meteorological stations in the UK are available from *Met Office Integrated Data Archiving System (MIDAS) land and marine surface stations (1853–current)*, made available by the NCAS British Atmospheric Data Centre (http://badc.nerc.ac.uk). The measurement is a simple one: Met Office observers simply record a thunder day on any day they hear thunder (Lewis, 1991). There is no formal training in discriminating between thunder and false positives, and there is no stipulation to use any additional instrumentation for verification (J. Wilkinson, pers. comm.). In practice, however, on the suspected identification of thunder, observers may on occasion also consult radar data or radio lightning observations (or 'sferics') if/when available (P. Inness, pers. comm.). Conversely, it is not possible for a thunder day to be recorded without the observer having heard thunder, thus distant bright fireworks confused with lightning flashes should not result in false positives in the thunder day record.

Prior to 1950, thunder days were recorded in the climatological returns of manned UK stations, with monthly totals available in the Monthly Weather Report. In the MIDAS daily dataset, thunder day records routinely began in 1950, with the number of manned UK stations making such observations limited to fewer than 10 until 1957 and fewer than 100 until 1971. After this date, there were approximately 400 stations making thunder day observations, though it unfortunately slowly tapered off after 2000, to fewer than 200 again at the end of 2010 (see also Perry and Hollis, 2005 and Figure 1(a)). Due to the difficulty in discriminating between an observation of no thunder and no thunder observations, any station making a single observation of thunder in a given year is assumed to be actively observing and is included in the analysis. *T*, the fraction of UK observing stations which recorded thunder on a given day, is constructed from individual station data.

Multi-shell rockets and slow-burn composite fireworks are most likely to be mistaken for thunder (pyrosociety.org.uk, pers. comm.). It is difficult to obtain data on the widespread use of such fireworks in the UK, but anecdotally at least, they appear to have been in widespread public use for Bonfire Night celebrations since at least the early 1980s. Thus this study primarily considers the period 1980–2010. Changing the start year for this interval by ±10 years does not qualitatively change the results reported in this study, as discussed later. Figure 1(b) shows daily (black) and annual (red) *T* values. As expected, there is a very strong seasonal variation in *T*. There is some evidence of a change in the annual mean *T* associated with the increase in the number of stations from 1950 through to the early 1970s. After this time, there does not appear to be any immediate correspondence between changes in the number of stations and annual *T*, suggesting that the spatial distribution of reporting stations is not changing dramatically through the period of interest (1980–2010).

In order to compare the reporting of thunder on 5 November with the rest of the year, it is necessary to subtract the strong annual variation which dominates thunderstorm occurrence. Mean *T* for each day of the year is computed over the whole 1980–2010 period (the black lines in Figure 2). In order to make an annual climatology, a 50-day running mean of the annual composite is computed (the red line in Figure 2), denoted by *T50*. The size of this smoothing window does not qualitatively affect the results presented here, as long as it is greater than ~10 days and shorter than ~6 months. The climatological deviation is then taken to be the difference between the smoothed and unsmoothed value (i.e. *T – T50*). As the magnitude of the climatological deviation will be much greater during times of higher average *T* (summer) than lower average *T* (winter), the fractional climatological deviations, ΔT, are computed (i.e., $\Delta T = [T - T50]/T50$).

Organised firework displays and private firework use may occur on a number of days around 5 November, particularly in years when it falls during the middle of the week and the celebrations are shifted either forwards or backwards to the weekend. If it assumed that fireworks use is focussed on the Friday or Saturday closest to 5 November, then on average this will mean fireworks use is within ±1.3 days of fireworks night. To capture this, a 3-day running mean is applied to ΔT, yielding $\Delta T3$. This may miss some activity in years when fireworks celebrations are split between the weekends before/after 5 November, but this is preferable to over-smoothing the whole dataset and removing the possible signal.

An annual composite of $\Delta T3$, centred on 5 November so as to allow for leap days, is shown for the 1980–2010 period in Figure 3(b). In this annual composite, there is clearly no evidence for an increase in the false-positive reporting of thunder due to fireworks. In fact, 5 November has the lowest mean $\Delta T3$ value.

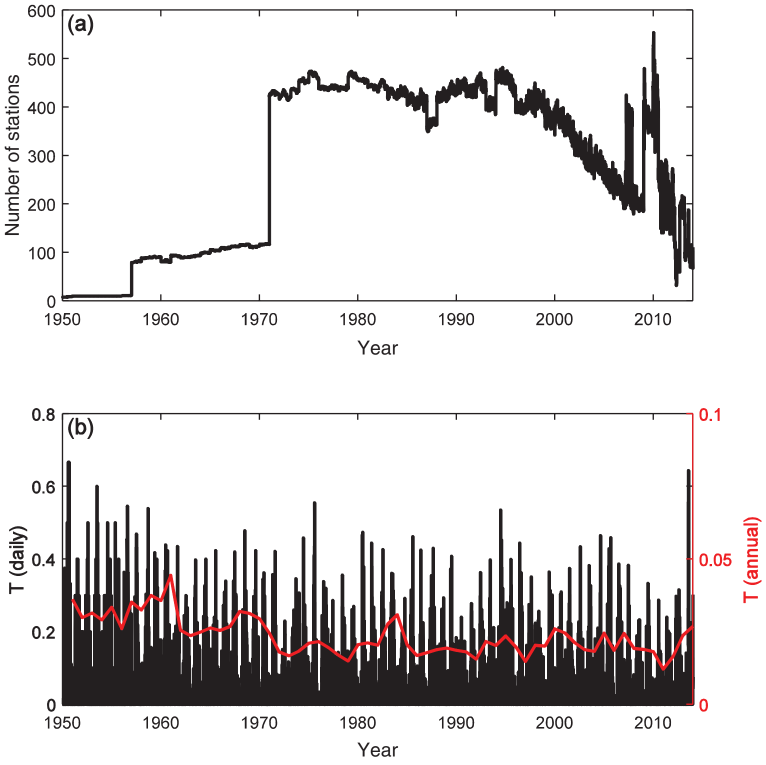

Figure 1. (a) The number of stations making thunder day observations. (b) The daily (black and left-hand axis) and annual (red and right-hand axis) values of T, the fraction of UK stations reporting thunder on a given day.

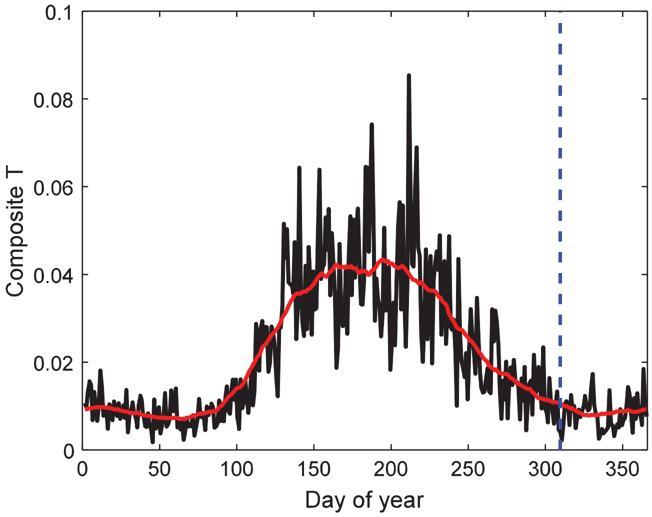

Figure 2. A composite of the annual mean variation in T for the period 1980–2010. Black lines show the daily values; red lines show 50-day running means. The blue dashed line shows 5 November (for non-leap years).

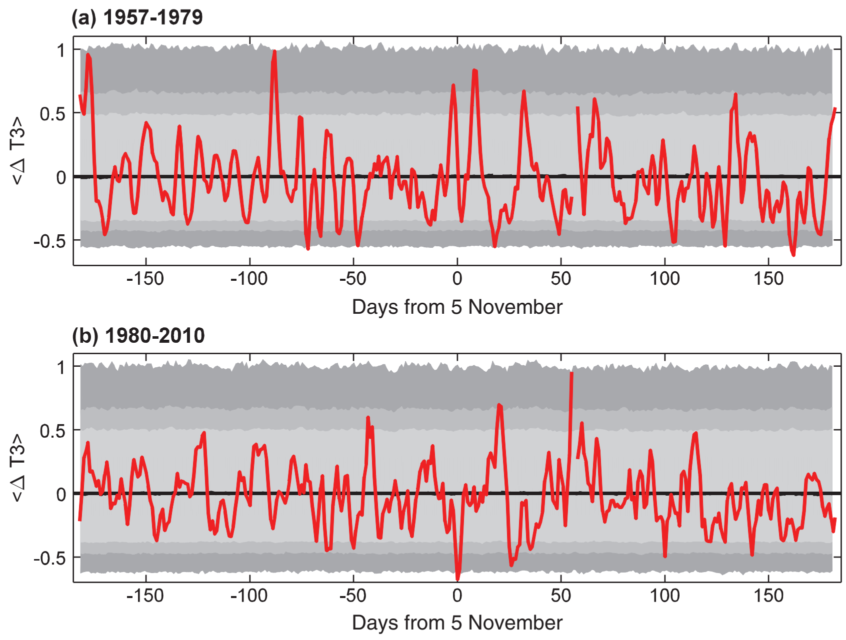

Figure 3. Mean fractional climatological deviation of thunder days, $\Delta T3$, about 5 November, where (a) shows the period 1957–1979 and (b) shows the period 1980–2010. The grey-shaded areas show the intervals containing 90, 95 and 99% of the variations from a Monte Carlo sampling of $\Delta T3$ in the given period. Note that in (b) there is no evidence for an enhanced false-positive rate around 5 November. In fact, $\Delta T3$ on 5 November is the lowest observed, suggesting a systematic under-reporting of thunder.

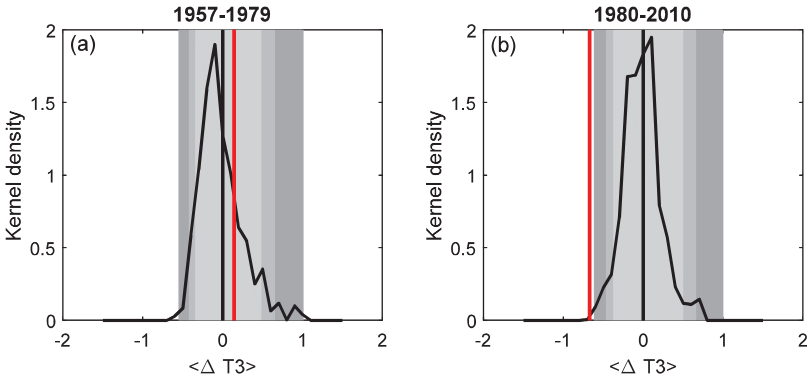

Figure 4. Probability density functions, computed from kernel density, of $\Delta T3$ for the (a) 1957–1979 and (b) 1980–2010 periods. The grey-shaded areas show the intervals containing 90, 95 and 99% of the variations from a Monte Carlo sampling of ΔT in the given period. The red lines show 5 November.

The most basic estimate of the probability of the lowest $\Delta T3$ value falling on 5 November purely by chance is that it is 1/N, in this case approximately 1 in 365 (or closer to 1 in 100 if the 3-day smoothing window is considered). But it is more important to quantify the probability that such a value (<$\Delta T3$> = –0.67) falls within the natural meteorological variability present in the data. The following 'Monte Carlo' approach is taken. Instead of using 5 November in each year as the t = 0 time for the composite to produce <$\Delta T3$>, random times throughout each year are selected and a new <$\Delta T3$> computed. This is done 10 000 times. The grey-shaded panels on Figure 3 show the bands which contain 90, 95 and 99% of the <$\Delta T3$> values about these randomly selected times. It can be seen that 5 November is below the 99% band, also suggesting an approximately 1-in-100 probability of the low value occurring purely by chance. (Note, however, that this test implicitly assumes the annual variation has been adequately removed by the climatology.) Figure 4(b) shows the probability density function of <$\Delta T3$> for the 1980–2010 period, using a kernel density estimate. It can be seen that while 5 November has the lowest <$\Delta T3$> value, it sits at the edge of the overall variability rather than being an extreme outlier. Finally, as a simple test of the robustness of this signal, individual decades of data within this period are considered. For the years 1980–1989, 1991–2000 and 2001–2010, <$\Delta T3$> = –0.64, –0.51 and –0.86, and the rank within the distribution is 15, 53 and 2 of 365, respectively. So in all cases, 5 November is well below climatology (though the climatology itself will be poorly described for such short intervals).

Note that Figure 3(b) also shows a large positive peak in <$\Delta T3$> at t = 55 days, corresponding to 30 December. It is only significant above the meteorological variation at the 95% level and only present in the 1990–1999 data, not in the 1980s or 2000s. Its possible relation to fireworks displays associated with New Year's Eve celebrations is discussed later.

As a comparison with the 1980–2010 period, wherein UK fireworks use around 5 November is expected to be widespread, the earlier period, 1957–1979, is considered here. 1957 is taken as the start date as the number of stations rises to approximately 100 (see Figure 1(a)). Unfortunately, there is a large jump in the number of stations in the early 1970s, but limiting the period to 1973–1979 reduces the meaningfulness of the climatology required to compute $\Delta T3$, which is even less desirable. With this limitation in mind, Figures 3(a) and 4(a) show the analysis for 1957–1979. From the asymmetric probability distribution function, it is clear the change in the number of stations is having an effect. Nevertheless, it can be seen that 5 November for this period lies somewhere within the middle of the <$\Delta T3$> variability. Also of note is that there is one point below the 99% lower bound (<$\Delta T3$> = –0.62 at +162 days from 5 November, i.e. 25 or 26 April). This is to be expected as part of the normal meteorological variability (i.e. by definition, 1 point in 100 should be outside the 99% band on average).

Discussion and conclusions

Audible thunder records, or 'thunder days,' are expected to be susceptible to false positives, particularly from explosions. Thus, in the UK, one might reasonably expect an over-reporting of thunder on and around 5 November. Fireworks experts were split on the issue, with some expressing doubt that shells and rockets would be mistaken for thunder, while others argued that fireworks are, on occasion, mistaken for thunder, particularly multi-shell fireworks and slow-burning compositions (pyrosociety.org.uk, pers. comm.). In fact, no increase in thunder, relative to climatology, is found for the 1980–2010 period, when the signal is expected to be most pronounced. Similarly, there is not strong evidence for an enhancement in thunder reporting on New Year's Eve, as the peak is on 30 December and celebrations are not traditionally spread around that time. Furthermore, the peak is only present in the 1990–1999 interval and not 1980–1989 or 2000–2009. Thus there is no direct evidence for false positives in the thunder day data as a result of fireworks.

In fact, around 5 November for 1980–2010, there has been a dearth of thunder reported (relative to the climatological variation). A similar drop in reported thunder is not found for 31 December, but New Year's Eve firework displays are a more recent phenomenon and personal firework use remains more limited. The apparent lack of thunder for 5 November is at the edge of the observed variability in the data, so chance of simple meteorological variation cannot be completely ruled out. But an alternative explanation of observer bias seems more plausible. Audible thunder records are not compiled by an unthinking listening device or computer algorithm. They are put together by human observers, which come bundled with 'a priori' knowledge that around 5 November there are a lot of loud noises which, they believe, can be mistaken for thunder. Thus they will be more likely to 'second guess' (Pliske *et al.,* 2004) any potential thunder observation as a false positive resulting from loud fireworks. The results presented here suggest observers are actually playing it too safe. The actual probability of an observer mistaking fireworks for thunder is much lower than the observer assumes. Thus observers should trust more in their ability to discriminate between thunder and fireworks.

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References

Brooks CEP. 1925. *The Distribution of Thunderstorms Over the Globe*. Her Majesty's Stationery Office: London.

Changnon SA. 1985. Secular variations in thunder-day frequencies in the twentieth century. *J. Geophys. Res.* **90**(D4): 6181–6194.

Kitagawa N. 1989. Long-term variations in thunder-day frequencies in Japan. *J. Geophys. Res.* **94**(D11): 13183–13189.

Lewis RPW. 1991. *Meteorological Glossary*, 6th Edition. Her Majesty's Stationery Office: London.

Owens M, Scott C, Lockwood M *et al.* 2014. Modulation of UK lightning by heliospheric magnetic field polarity. *Environ. Res. Lett.* **9**(11): 115009.

Perry M, Hollis D. 2005. The generation of monthly gridded datasets for a range of climatic variables over the UK. *Int. J. Climatol.* **25**(8): 1041–1054.

Pliske RM, Crandall B, Klein G. 2004. Competence in weather forecasting, in *Psychological Investigations of Competence in Decision Making*. Shanteau J, Johnson P (eds). Cambridge University Press: Cambridge, UK, pp 40–70.

Rampino MR. 1989. Distant effects of the Tambora Eruption of April 1815: an eyewitness account. *Eos Trans. Am. Geophys. Union* **70**(51): 1559–1559.

Romps DM, Seeley JT, Vollaro D *et al.* 2014. Projected increase in lightning strikes in the United States due to global warming. *Science* **346**(6211): 851–854.

Stringfellow MF. 1974. Lightning incidence in Britain and the solar cycle. *Nature* **249**: 332–333.

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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.

I attach a photograph taken on a recent visit to the island of La Palma which is the westernmost of the Canary Isles (not to be confused with the port of La Palma on Gran Canaria) This island consists of an enormous caldera – the Caldera de Taburiente in the north rising to 7000–8000ft and a long ridge running south from this. This ridge is relatively low in the middle section (the Cumbre Nueva) with a height of around 4700ft rising to over 6000ft further south (the Cumbre Vieja). The island lies in the trade wind zone with a prevailing NE'ly wind averaging around 15–20kn under the trade wind inversion. The cloud on the western side of the island is critically dependent on the height of this inversion. If it is below 4000ft the flow is blocked and skies are usually clear in the west. If it is above 8000ft there are clouds with sunny intervals in the west. On many occasions the inversion lies at around 5000ft. In this case the flow is blocked north and south but can flow over the central Cumbre Nueva. If the flow over this ridge is supercritical – i.e. exceeds the critical speed for waves on the inversion – then a lee slope wind blows down into the valley. In this case the cloud formed by ascent on the windward side of the ridge dissolves immediately as it sinks to the west of the ridge and the formation has the appearance of a waterfall. These are the conditions shown in the attached photograph in which can be seen the impressive cloud formation.

Alan Lapworth
Sharnbrook, Bedford

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