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Situating 1816, the 'year without summer', in the UK

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The immediate local impacts of the eruption of Mount Tambora, Sumbawa, Indonesia in April 1815 were devastating, resulting in the loss of an estimated 60 000 lives on this and neighbouring islands. However, the longer term effects of the largest known historical eruption on global weather and climate and the related consequences for human health and wellbeing have maintained the prominence of the eruption in public memory. Among the most notable effects were global weather anomalies the following year, which has come to be referred to as 'the year without summer'. Scholars across the sciences and humanities continue to investigate the eruption, seeking insights into the likely meteorological and societal impacts of future volcanic eruptions. The bicentenary of the 'year without summer' in 2016 provides a timely moment to revisit this weather episode. In this paper, we draw on a range of archival materials and contemporary publications to reconstruct the weather year and explore how the summer of 1816 was experienced and recorded across the UK. We also wish to demonstrate the importance of historical contingency in understanding the potential implications of the event at the local level, and of situating events within their appropriate temporal context. We do this by considering the summer of 1816 as set against the wider weather and cultural contexts of the 1810s. Our findings illustrate that in a UK context, summer 1816 was characterised by unusual and extreme weather events. Importantly it also took place within a sequence of years that were similarly replete with anomalous and challenging weather conditions.

KEY WORDS: UK, Tambora, 'year without summer', documentary record, extreme weather, 1816

Tambora and the 'year without summer'

'Volcanic eruptions represent some of the most climatically important and societally disruptive short-term events in human history' (LeGrande and Anchukaitis 2015, 46). The eruption of Mount Tambora, Indonesia represents the largest known eruption in recorded history (Lamb 1970; Newhall and Self 1982). It released an estimated 53–58 Tg ($5.3–5.8 \times 10^{13}$ g) of sulphur dioxide within a period of about 24 h on 10–11 April 1815 (Self *et al*. 2004). Sulphate aerosols entered the stratosphere and made their way around the world, temporarily cooling the atmosphere in what was already proving to be a cold decade. The effects were felt across the northern hemisphere (Raible *et al*. 2016), and have led to the following year being referred to as the 'year without summer' (Harington 1992). Two centuries on, there is still much to learn from Tambora, particularly its effects on global climate and local weather as well as the associated consequences for human health and wellbeing (Robock 2015).

The bicentenary of the eruption in April 2015 renewed scholarly and popular interest in the climatic consequences of eruptions and so-called super eruptions (Hegerl *et al*. 2011; Luterbacher *et al*. 2016; Raible *et al*. 2016; Timmreck 2012; Zanchettin *et al*. 2013)[1]. Recent research has focused on the possible correlations between volcanic activity and El Niño events (Adams *et al*. 2003; Emile-Geay *et al*. 2008), and positive NAO conditions and winter warming two years after strong volcanic eruptions (Ortega *et al*. 2015). Following significant disruption in Europe from smaller recent eruptions (Donovan and Oppenheimer 2011) some used the moment to ask whether the world was prepared for 'the next volcanic catastrophe' (Kandlbaeur 2013; McGuire 2015). It is thus timely to revisit summer 1816, a season that constitutes 'a remarkable case study for the exploration of various direct and indirect interactions between climate variability and human history' (Luterbacher and Pfister 2015, 247).

However, as Sadler and Grattan (1999) warn, eruptions are too regularly invoked as major causal

factors in a range of studies that examine palaeoenvironmental processes. There has been a tendency to conflate volcanic events with 'major turning points in world history' (Oppenheimer 2015, 244)[2] and to overlook the role of prevailing climatic, social and environmental conditions (Hansen and Lacis 1990; Nicholls 1988 1990). As Grattan (2006, 11) explains, the processes operate on 'quite an intimate scale', and it is thus important to also explore the impacts at the local scale, paying attention to the particularities of weather (Piper 2004), but also socio-economic and cultural circumstances in specific places and at particular points in time (Endfield 2011 2014; Hulme 2008 2009; Livingstone 2012). Moreover, as we begin to understand more about the specifics of the eruption, discovering more about Tambora's effects on distant places and peoples through 'forensic interdisciplinary studies' (Oppenheimer 2015, 245) may well prove useful in determining the risk of, and vulnerability and response to future events.

In this paper we explore geographically grounded narratives of the weather of 1816, contextualise the emergent weather history within a longer reconstruction of weather and weather-related events for the second decade of the nineteenth century, and situate these reports within the socio-economic context in which they were produced.

Volcano weather and impacts in context

Recent review articles have summarised what is known about the Tambora eruption and its implications for the Earth system as recorded through early instrumental observations, climate proxies, geological evidence, climate reconstructions and model simulations. The 1816 climate anomaly has been relatively well studied in the United States (particularly in New England) and parts of Europe. In the UK the summer of 1816 has long been recognised as one of the most unseasonable on record, and the July is the coldest July within the Central England Temperature series (extending back to 1659). However, 1695 and 1725 had colder summers (Manley 1974; Raible *et al*. 2016). The known cooling effect of volcanic particles in the atmosphere means that most research has looked at the impact of volcanic eruptions on temperature. Dawson *et al*.'s (1997) analysis of a gale record for Edinburgh indicates a possible link between high magnitude volcanism and winter storminess, whilst recent studies suggest that global rainfall decreases following large eruptions (Iles *et al*. 2015). The England and Wales precipitation series (1766–present day) places summer 1816 23rd wettest, with 1817 wetter (Wigley *et al*. 1984; Alexander and Jones 2001; HadUKP 2016).

As well as considering the range of meteorological effects it is thus also important to explore the weather of 1816 relative to that of preceding and succeeding years. Tierney *et al*. (2015, 226) describe the early 1800s as an 'exceptionally cold period in the Indo-Pacific region'. The 1810s are also among the coldest decades recorded over Europe and the northern hemisphere (Rampino *et al*. 1988, 83), since comparable records began about 1750 (Briffa and Jones 1992), and perhaps even in the last 500 years (Guevara-Murua *et al*. 2014). Oppenheimer (2003) recognises the summers of 1817 and 1818 as abnormally cold in the northern hemisphere. Yet, as Briffa and Jones (1992) point out, many studies of the 'year without summer' have neglected to consider the weather and climate of the rest of 1816 let alone the decade of the 1810s. Several reasons have been forwarded for the cool decade. One is the so-called *Dalton minimum of solar activity* between 1790 and 1830 (Solanki *et al*. 2004), when sunspot numbers were reduced (Hoyt and Schatten 1998; Vaquero 2007) and solar irradiance was lower (Lean *et al*. 1995; Mann *et al*. 1998; Stendel *et al*. 2006; Wagner and Zorita 2005). A second is a period of unusually high levels of volcanic activity (Guevara-Murua *et al*. 2014; Lamb 1970). In a UK context, 'the bad weather phenomena reported cannot be indiscriminately assigned to the eruption of Tambora' (Sadler and Grattan 1999, 187).

The socio-economic and political context in which this unusually cold period played out was significant, coinciding with the 'dislocations' associated with the Napoleonic wars (Post 1977) and the profound and pervasive effects on local, national and international economies and trade (O'Rourke 2006). However, Wood (1965, 6–7) supposes that, 'In 1816 there occurred depths of suffering among the people beyond the limits that could rightfully have been expected even in a transition from war to peace', concluding that a 'chance coalescence' of the paths of the worsening economy, agricultural depression, post-war adjustment and the fluctuating but generally inclement climate was to blame. Disentangling the cultural impacts of the possible weather event associated with Tambora from this context of disruption and hardship is challenging.

Documenting Tambora

There are a number of well known documents detailing both the eruption of Tambora (Raffles 1817 1830; reviewed in Oppenheimer 2003; Stothers 1984), and the weather of the following year(s) (Howard 1818; von Clausewitz 1922 in Oppenheimer 2003). Indeed, the conditions of 1816 may have motivated people to write more generally about the weather (Munger 2015). In the North American context, scholars have used newspapers (Skeen 1981) and diaries (Baron 1992; Hoyt 1958; Hughes 1979; Ludlum 1966; Munger 2014; Stommel

and Stommel 1979) to reconstruct a series of unseasonable frosts in June and July 1816. In Europe, the writing of Mary Shelley and Lord Byron has been used to provide insight into summer 1816 in Geneva (Wood 2014), while Luke Howard's meteorological observations (1806–17) provide an instrumental record of pressure, temperature and rainfall for London, with reference to events throughout continental Europe (Howard 1818). Other analyses relate to documentary sources in Iberia (Trigo *et al*. 2009) and Canada (Hamilton 1986). Ship logbooks also provide valuable insight into the worldwide pattern of weather and climate in 1816 (Chenoweth 1996). It is now possible to create synoptic weather maps for particular events within 1816 from historic instrumental data (Brugnara *et al*. 2015) and to use reanalysis to create visualisations of surface pressure for that year (Compo *et al*. 2015)[3].

Given the wealth of potential source material there has been surprisingly little use of archival documents to reconstruct the weather of 1816 in the UK, exceptions working with single diary sources (Lee and MacKenzie 2010; Wheeler 2016). In the sections below we draw on diaries, correspondence, and other unpublished documents (Table 1) to revisit the weather of the summer of 1816, and the 1810s[4]. Documents have been identified as providing narrative information on the weather for the study period and are not exhaustive so much as representative of that available in the collections consulted. We deliberately avoided searching for Tambora as a known event. Manuscript sources are supplemented with extracts from contemporary publications in order to give a sense of the circulation of weather information.

Situating Tambora

As Tann (1980, 45) has argued, 'crop failure was a fact of life' for many people across the UK throughout the eighteenth century. Runs of poor harvests, such as those of the 1790s and early 1800s (notably 1798–1801), which have been linked to the generally cold conditions that prevailed at the end of the eighteenth century (Luterbacher *et al*. 2004), were far more damaging than single bad years. Grain shortages in the early 1800s (Corrigan 1847; Hopkinson 1800; Post 1977) provide a context in which the weather anomalies of the second decade of the nineteenth century took effect. Table S1 in the Supplementary Information provides a summary of extreme weather events in the UK during the period 1809–1818.

Before Tambora: January 1809–April 1815 January 1809 was characterised by very low temperatures and frequent and heavy falls of snow. A Worcester newspaper reported on 1 February:

> In consequence of the sudden and rapid thaw which commenced yesterday … almost every river in the Kingdom has overflowed its banks and immense tracts of land have been land under water … On Sunday the water on the north Parade was only 9 inches lower than it was in the great flood of 1795 and about 18 inches below the edge of the plate which is placed, near the Cathedral to commemorate the great flood of 1770.
>
> WRO, 899/749xii[5]

Temperatures fluctuated dramatically in spring and summer with some violent storms. In Clifton, Nottingham, Joseph Woolley noted on 10 August:

> there was a very bad thundering and lighting night… about 'alf past ten o'clock of night it was very terrible almost all of the night there 'as been a deal of thunder and rain and 'ail this week more than of ever remember at this time of the year in my life.
>
> NA, DD 311/4

The winter was relatively mild and 1810 began, according to Robert Lowe, 'summer like' (NA, DD/SK/217/14). However, in the Midlands from the 13 January throughout February and into March, freezing conditions with snow and hard frost affected young crops. Peter Pegge Burnell reported on 25 February how there were 'very severe storms of hail & snow', whilst the middle of the month had been 'very severe, vegetables terribly cut up of all sorts' (NA, DD/CW/8c/5/28). May brought night frosts and very little rain, checking vegetation growth. Summer was generally hot and dry with some areas in drought conditions.

A severe gale and high tide on 9–10 November caused coastal flooding, shipwrecks and significant loss of life and livestock in the east of England, as well as damage to trees and buildings across the Midland counties. Reverend James Windsor, clerk of Uffculme, Devon, recorded how the weather was 'unusually boisterous' at this time, 'violent hailstorms accompanied with vivid lightning & loud thunder happened frequently' (DeRO, 1920A/PI/16). Britain's strongest tornado on record struck Hampshire on 14 December (Doe 2016).

Winter 1810–1811 was cold with sharp frosts, high winds, and deep snow. Freezing weather combined with depressed economic wellbeing, a function in part of trade embargos and restrictions at the tail end of the Napoleonic wars, meant that life was becoming extremely difficult for the poorer sectors of society. In Nottingham, by February, 'Such was the reduced state of trade, and the high price of corn, that half-famished workmen, belonging to nearly every branch of the local manufacture, were constrained to sweep the streets for a paltry support. They were so employed by the overseers of St

Table 1 Key sources for the weather of 1809–18

Document, repository and catalogue reference/publication details	Temporal coverage	Geographical coverage	Notes on author and weather content
Unpublished sources			
Diaries			
Abbot Upcher NRO UPC 155	1813–16	Sheringham, Norfolk	Upcher was a young squire who purchased the Sheringham estate in 1811. Describes weather in relation to work on the hall and estate
Joseph Woolley NA DD 311/1–6	1801–15	Clifton, Nottinghamshire	Framework knitter and stocking maker. Diaries detail episodes of extreme weather
Peter Pegge-Burnell NA DD/CW/8c/5/1–57	1748–1834	Winkburn Hall near Newark, Nottinghamshire	Farmer and landholder. Diaries detail weather and farming matters in short daily entries
Robert Lowe NA DD/SK/217/1–26	1795–1822	Various locations in Nottinghamshire	Lowe was High Sheriff of Nottingham (1802), and author of *General view of the agriculture of the county of Nottingham* (1798). Short daily entries detailing weather
Richard Phillips Shilton NA M457–8 and M491	1808–34	Southwell, Nottinghamshire	Author of *The history of Southwell* (1818). Daily notes on the weather
Walter Davies (Gwallter Mechain) NLW MS 1762 Bi–ii	1797–1822	Various locations around Wales	Commissioned to conduct agricultural surveys of Wales (published in 1810 and 1815) for the London-based Board of Agriculture. Almost daily notes on weather
Correspondence			
Bosworth Hall LLRRO DG39/708, 718, 720, 726, 792, 796, 1153, 1786, 1983	1783–1853	Bosworth, Rowell, Leicestershire; Drayton, Berks and Welford, Northamptonshire; Heythrop, Oxon	Letters from land agents to Francis Fortescue Turvile reporting on weather as it related to estate matters
Earsham Hall NRO MEA3/591, 596, 606-608, 613	Mainly 1815–47	Earsham, Denton, Norfolk; Bungay, Suffolk	Letters from land agents William Spence, Margitson, Thomas Spilling and Edmund Woolterton to Sir William Windham Dalling reporting on weather as it related to estate matters
Fitzherbert estates DRO D239/M/E and F	1801–38	Tissington, Derbyshire; Rhayader, Powys; Aston, Yorkshire	Letters relating to the Tissington estates of Sir Henry FitzHerbert (James Hardy at Tissington, John Jones at Rhayader and William Alderson at York)
Longsdon DRO D3580/C	Mainly 1757–1850s	Little Longstone, Derbyshire	Letters exchanged between members of the Longddon family who were large landowners. From the 1770s the family had interests in the cotton manufacturing industry in Derbyshire and in the United States
2nd Lord Walsingham NRO WLS/XLVIII/1-74	1770–1821	Rackheath, Norfolk and London	Letters exchanged between Thomas de Grey, 2nd Lord Walsingham, peer and politician with land agents, reporting on weather as it related to estate matters
Other			
Clipston Parish Register NoRO 70P/03	1730–1818	Clipston, Northamptonshire	Records of baptisms, marriages and burials and memoranda about the weather *c*. 1787–1818

Table 1 *Continued*

Document, repository and catalogue reference/publication details	Temporal coverage	Geographical coverage	Notes on author and weather content
Meteorological Record Boulton and Watt Soho Manufactory BCA MS3147/9/36-41	1793–1830	Soho, Birmingham	Thrice daily weather observations by drawing office staff in button, buckle, box, and toy factory, Birmingham
Contemporary publications			
Farmers' Magazine (Branch III, 'Agricultural Intelligence')	1800–25	England, Scotland and Wales	Published quarterly from January 1800 by Archibald Constable & Co of Edinburgh. Edited by Robert Brown of Markle and Robert Somerville of Haddington. Succeeded by *The Farmer's Register and Monthly Magazine* and *The Quarterly Journal of Agriculture in Scotland*; and by *The British Farmer's Magazine* in England. Volume 17 (1816) contains 100 references to 'weather'
The agricultural state of the kingdom, in February, March, and April 1816; Being the substance of the replies of many of the most opulent and intelligent landholders to a circular letter sent by the Board of Agriculture to every part of England, Wales and Scotland	February–April 1816	UK	Commissioned by the Board of Agriculture and published by Charles Clement, London. Primarily prompted by a crisis in rents and increasing abandonment of farms
Gentleman's Magazine	1731–1907	UK wide	Founded in London by Edward Cave as a monthly digest of news and commentary on wide ranging topics
Agricultural report, *The Observer*	–	UK wide with some reference to Europe	Short and general summaries. Published monthly
The climate of London: deduced from meteorological observations made at different places in the neighbourhood of the metropolis	1806–January 1817	London, plus some information from news reports from around the UK and Europe (including Howard's own journey in 1816) and North America	By Luke Howard, published in 1818. Tables of instrumental observations of wind direction, min and max pressure and temperature, hygrometer at 9am and rainfall. Accompanied by daily descriptive notes and summary statistics

Source: Only sources on which we have drawn substantially appear in this table. Other documentary sources are fully referenced in the text using the same conventions; Birmingham City Archives (BCA), Derbyshire Record Office (DRO), Devon Record Office (DeRO), Herefordshire Record Office (HRO), Leicester, Leicestershire and Rutland Record Office (LLRRO), Lincolnshire Archives (LA), National Library of Wales (NLW), Nottinghamshire Archives (NA), Norfolk Record Office (NRO), Northamptonshire Record Office (NoRO), University of Nottingham Manuscripts and Special Collections (UNMSC), Worcestershire Record Office (WRO).

Mary's[6], the workhouse being too full to receive their families, and no other employment presenting itself' (Sutton 1852, 289). The spring that followed was little better, with frosts and snow on the 7–10 April. On 13 May a tornado struck Derbyshire tearing up large trees, whilst violent hail broke glass in Herefordshire and Worcestershire. Two weeks later another damaging hailstorm affected the same

vicinity, this time accompanied by flooding that swept away a number of people and buildings.

The summer of 1811, like that of the previous year, was predominantly wet across the UK and Ireland. Heavy rains on 20–22 July caused serious localised flooding and washed hay from the fields in Leicestershire, though for the most part both hay and corn harvests were regarded as good this year. Across much of Wales, however, this summer was one of great heat and drought and the situation was described by Walter Davies as 'precarious' (NLW, MS 1762 B ii). The autumn was generally mild across England, and in Wales finally wet, while the final days of the year were very cold with snow in many parts. This cold spell was to be prolonged and hard frosts and snow prevailed into the summer of 1812.

Civil disturbance was not uncommon in late eighteenth and early nineteenth century England and has been attributed to a range of complex factors (Thompson 1971). The calamitous state of trade and pitiable harvests of 1809–12 were among the key drivers of several waves of rioting as 'banks failed and export trade collapsed' (Rudé 1959, 80). The hosiery centres of Nottinghamshire, Derbyshire and Leicestershire were severely affected, and rioting occurred, including that associated with the Luddite uprising (Lindholdt 1997). For example, on 11 September 1812 in Nottingham, 'a riot, engendered by the prevailing famine, commenced in the morning' (Sutton 1852, 301). There were generally favourable conditions in autumn, and a plentiful, albeit delayed wheat harvest triggered a temporary fall in prices.

1813 also began very fine before a short cold snap. February brought stormy conditions with strong winds, particularly on 16 February when Woolley recorded 'maney stacktops blown off and some were blown over the wind had been very boisterous for a fortnite or more but it was the worst on that day . . .' (NA, DD/311/5). While March 1813 was fine and from 8 April it was hot and likened to summer, the last 10 days of the month brought cold, frost and hail storms, and May was dominated by heavy showers and flooding. Pegge Burnell notes how 17 June was 'black and cold as xmas', and the 'very cool and gloomy' conditions resulted in 'backward' vegetation (NA, DD/CW/8c/5/31). There are indications that conditions improved to contribute to a relatively successful harvest in some areas. A very rainy and windy start to September, however, damaged and delayed the harvesting of some crops, including hops. Worse was to come, as one of the most severe winters in English history was about to grip the country.

The winter of 1813–14 has been discussed elsewhere as exceptionally cold (Pearson 1975). A severely cold spell began at Christmas 1813 and continued for eight weeks. By 14 January it was 'very cold and the hardest frost ever known' so much so that 'many people froze to death' (NA, DD/SK/217/18). William Haynes, in Bosworth, Leicestershire, felt that the snow which was 2 or 3 ft thick would at least 'preserve many things', and lead to a drop in the price of some grains, specifically oats (LLRRO, DG39/737). Pegge Burnell was driven to exclaim at the end of the month, 'God have mercy on thine creatures, this day towards night still worse, the barometer almost out of sight – snow 10 inches deep upon the level – drifts as many feet' (NA, DD/CW/8c/5/33).

Such heavy snowfalls caused disruption and drama across the country. On 10 January, seven boys drowned in the River Trent in consequence of the breaking of the ice (Toone 1826). Fuel was in short supply, coal prices escalated and agricultural operations were delayed. Around the country, efforts were made to relieve the poorer sectors of society. A meeting of the inhabitants of the town and parish of Cullompton, Devon was held on 22 January, 'for the purpose of considering the best means to be adopted to relieve the poor of the said Parish from the distressed and necessitous situation in which they are at present from the inclemency of the weather'. It was resolved that 'all persons whose ability will enable them will compassionate the sufferings of the poor to whom it is intended to give more than ordinary relief' (DeRO, 2404A/PO 215–216). Similar moral economic responses are noted in other parts of the country. Local land owner Francis Fortescue Turvile 'distributed to 55 famerlys [sic] in bread to the amount of 4£ 7s –d witch [sic] was received with a many thanks' in Husbands Bosworth, Leicestershire (LLRRO, DG39/720).

After a dark, wet and cold start to spring, it remained very cold with some snow and sharp frosts though May, while June was also cold. July brought storms, including what for Richard Phillips Shilton was 'the most violent storm of hail and rain ever remembered' (NA, M491). The storm caused extensive damage to crops in Leicestershire and Nottinghamshire and, according to local council minutes, seems to have represented something of a tipping point for an already afflicted agrarian population who stood 'in need to assistance' at this time (LLRRO, QS118/6). By the end of August the weather became very hot though the wheat crop was poor and mildewed. Low temperatures characterised the year, while frost and snow heralded 1815 and continued into March and April.

The period between 1809 and spring 1815 was thus one of considerable hardship, associated with anomalous weather, set against an already difficult socio-economic and political context. By 1812, and in a context of general economic crisis triggered in part by war-related trade restrictions, the difficulties faced by some sectors of society, both rural and urban, contributed to popular protest and rioting.

The calamity continued with the severe winter of 1813–14. This context of socio-economic and environmental crisis provides the backdrop for the years of cooling, harvest failure and famine that have tended to be associated with the eruption of Tambora.

After Tambora: April 1815–1818 Summer 1815 was hot and dry. Edmund Woolterton wrote from Denton, Norfolk on 7 August, 'the drought has been so severe the park is short of feed . . .' and at High Wycombe, Buckinghamshire, spring water was sold for 3d per pail, about 1d a gallon (NRO, MEA 3/591). Across the country, violent winds and storms were experienced throughout the autumn.

Winter 1815–16 was severe, with heavy snowfalls interspersed with periods of flooding and strong winds, contradicting Stothers' (1999, 716) declaration that the 'first winters after the eruptions of AD 1815 [and AD1285] were quite normal'. Flooding on 5 and 6 January 1816 in the Irwell catchment was deemed greater than that experienced in 1768:

> washing down bridges, overflowing the banks of rivers, and carrying away cattle, banks, &c. The wind was nearly equally severe, and the snow was drifted into the roads so as to make them impassable for about two days, till opened by the spade, which is very unusual here . . .
>
> *Farmer's Magazine* [17 (1816), 125]

Some of the most severe conditions of the winter were experienced between 6 and 9 February. Lowe recorded, '6 Feb – it snowed hard all day & begun to frose (sic); 7 Feb – it snowed most of the night wind NE sharp frost; 8 Feb – a very deep snow & hard frost, about home all day' (NA, DD/SK/217/20). The severe winter weather was set against a depressed agricultural sector, as *The Observer*'s monthly agricultural report explained: '. . . many industrious and economical families, formerly in prosperous circumstances, are reduced to the lowest state of poverty' (4 February 1816, 4).

Spring was described as cold and 'backward' affecting vegetation growth. Luke Howard's observations in London suggested the average temperature was 8° lower than that of the corresponding period for 1815 (Table 2).

Geological and hydrological events may have contributed to a general sense of foreboding during spring 1816. An earthquake was felt across the Midlands and as far north as Liverpool on 17 March. Heavy downpours on 7, 12 and 13 April (the latter Good Friday and Easter Saturday) resulted in widespread flooding. That on the River Witham cut off Lincoln, and on the Trent and tributaries, washed away 'considerable quantities of soil, filling up soughs and ditches; and some Sheep have been lost' [*Farmer's Magazine* 17 (1816), 252]. Shilton thought it the 'greatest Greet flood known for 40 years', while Pegge-Burnell asked himself 'what flood – sure was never seen at this season, the glass nearly at changeable not withstanding it rained upwards of 30 hours' (NA, M/491; NA, DD/CW/8c/5/35). Hard night frosts damaged turnips, resulting in poor fodder for cattle. In Northumberland, 'there never was greater distress for want of food for livestock' [*Farmer's Magazine* 17 (1816), 252].

Table 2 Luke Howard's monthly meteorological observations for spring 1815 and 1816 (Howard 1818)

		1815	1816
March	Min temperature (F)	29	22
	Max temperature (F)	73	53
	Average temperature (F)	47.44	39.46
	Total rainfall (inches)	2.33	2.49
April	Min temperature (F)	28	24
	Max temperature (F)	70	59
	Average temperature (F)	48.56	39.66
	Total rainfall (inches)	2.09	1.56
May	Min temperature (F)	34	28
	Max temperature (F)	80	72
	Average temperature (F)	58.58	50.83
	Total rainfall (inches)	1.10	1.91

Howard observes in lunar rather than calendar months so the dates for observing periods do not exactly correspond from 1815 to 1816; the 1816 periods are earlier by *c.* 10 days which would be expected to exaggerate the temperature differential illustrated.

The unusually cold and black weather continued, with snow falling across the Midlands and Wales on 12 May. The parish register for Clipston, Northamptonshire records 28 May as a day of great hope:

> today may be called the 1st of summer . . . nature around us smiles & rejoices . . . trees of the blossoms which are now heaving will we hope in a few days boldly appear & in the summer being forth abundance.
>
> NoRO, CLIPSTON 70P/3

But June began cold; 'many wheat crops getting more and more yellow' and Lowe was forced to wear his 'great coat' for walking on the green in Southwell (NLW, MS 1762 B ii; NA, DD/SK/217/20).

A low-pressure system dominated in July, giving rise to very wet conditions. There were some hot days across the Midlands and Wales on 19–25 July, before continuous rains set in for 6–8 weeks:

> On 31 July [in Norfolk] the rain descended in such torrents as to prostrate the heavy crops in many places, & by the violent effects of a water spout, acres of turnips

> were washed away, & in some villages the ditches & lanes were so full of water that boats might have been rowed in them.
>
> Matchett (1822, 146)

Pastures were now 'full of grass' but continuous rain prevented cutting as Pegge Burnell recorded in his diary:

> 21 Aug – acres spoiling hay; 31 Aug – it began again to rain this morn about 3 o'clock & continued a dismal wet & cold day, night wind north west and very high – this was a most unseasonable month – pray God the next prove more favourable.
>
> NA, DD/CW/8c/5/35

The cumulative problems of a cold, wet summer were aggravated by crop-damaging storms.

September remained cold with sharp frosts. Abbot Upcher in Sheringham, Norfolk reflected: 'During this year there was no summer whatsoever. Incessant rains during June, July & August, and tremendous gales', whilst nurseryman Samuel Curtis wrote from Clumber Park, Nottinghamshire:

> The weather has been for a week past worse than ever, in addition to wet every day we have had frosty nights, Tuesday morning it was so severe that it has nearly killed all the French Beans & Potatoe tops, & I fear the Hops have suffered very much … I think we have the most unpropitious season ever remembered …
>
> NRO, UPC 155; UNMSC, Ne C 6396

Perseverance paid off for some: Susan Farington wrote to her cousin Antony Hamond (the former Sheriff of Norfolk) on 30 September to congratulate him for getting in the harvest, 'after a summer more unseasonable than any former one in my remembrance' (NRO, HMN 4/58/18). Those, like Hamond, who managed to harvest early were fortunate as on 7 October 'the rain fell in such torrents, as to occasion most alarming floods, and beat down the Barleys and others' [*Farmer's Magazine* 17 (1816), 519]. A great hurricane and snowstorm affected northeast Scotland on 20 October, and November was wet and very cold with severe frosts and snow, as Edward Stracey described:

> On the eighth of November I had apricots hanging on the trees waiting for the sun to ripen them; and on that day the frost was so severe as to freeze the water, the ice being an inch thick – In many fields in this neighbourhood the wheat standing in the sheaves is covered over with snow.
>
> NRO, WLS/XLVIII/30

The Farmer's Magazine [17 (1816), 481] summarised the harvest as 'uncommonly unpropitious', some comparing this with 'the memorable year 1799', others judging it beyond 'the recollection of the oldest person'.

Further discussion in the *Farmer's Magazine* centred on farmers' inability to pay rents, and many landlords were unwilling to offer abatement. Prompted by increasing farm abandonment the Board of Agriculture implemented a nationwide survey at the end of April 1816[7] . Responses described the lack of employment opportunities, with poor rates so high that in Wales the tax was collected in certain districts in goods rather than money. There is some suggestion in the *Farmer's Magazine* [17 (1816), 465] that the publication of the final report was supressed, possibly as part of a broader strategy 'to dampen grain speculation and to avoid social unrest' (Post 1977, 17).

Weather observers in 1816 were clearly aware of human distress across the country. On 18 March Davies wrote in his diary, 'Never or at least within memory of man, was such a time for general distress of the Nation …' (NLW, MS 1762 B ii). On 13 April, Lowe noted: 'was at the justice room many poor came for relief' (NA, DD/SK/217/20). Between 22 and 24 May, following a sudden rise in prices, farmworkers rioted in Littleport, Ely, Downham and Norwich in East Anglia (Griffin 2009; Oppenheimer 2003; Peacock 1965; Post 1977). As Peacock explains, 'the agricultural labourer was always the last to bestir himself – and when he did so it was a real indication of the deplorable conditions prevailing at the time, whether they were political, social, or economic' (1965, 11). At Tissington, Derbyshire, bailiff James Hardy suggested that if not for the kindness of Sir Henry Fitzherbert, 'more than two thirds of the Tissington labourers would want relief at this time' (DRO, D239/M/E/4535). Reverend William Alderson feared the winter would produce 'disturbances throu'out the country' (DRO, D239/M/F/8395). Stracey commented in a letter of 17 November that he endeavoured 'to find work for many hands', commenting that 'the people here [Rackheath, Norfolk] do not seem to be at all riotously inclined' (NRO, WLS/XLVIII/30). W. Palethorpe of Kirton in Holland included a postscript to his letter to his landlord that 'we have had extreme bad weather for the harvest and most shocking complaints of poverty' (NA, DD/1461/212).

Press reports detail the moral economic responses that followed. *The Gentleman's Magazine* [86 (1816), 79] reported that in Barnet:

> on Thursday [in July 1816], a Gentleman, happening to go into the market-place, found about 140 poor people literally starving; he ordered them all to be

> supplied with half a quartern loaf[8], and to come back next morning for another. On Friday the number that applied for relief was 338, when they got the same bounty. On Saturday morning those (all strangers) who applied were 776, who each received one-third of a quartern loaf, and from the parish a quarter of a pound of cheese each …

On 10 December in Nottingham:

> Owing to the scarcity of bread, good wheat readily realising 140*s* per quarter, there was much suffering and a great deficiency of employment. A public meeting on the subject was held in the Town Hall … The amount raised was 4,184*l*[9]. In addition to this liberal amount, the London Association contributed twenty tons of red herrings, Lord Middleton gave three hundred tons of coal, and the parish of St Nicholas expended 500*l* on a separate soup establishment.
>
> Sutton (1852, 326)

A system of night policing of the city was also introduced about this time as a result of an increase in robberies and disturbances. The Barnet and Nottingham situations appear typical – Wood calculated that during the winter of 1816–17 a total of 10 parishes of Dumfriesshire's 38, 'officially recorded the operation of a soup kitchen or the distribution of oatmeal to the poor' (1965, 9).

For the fourth successive year, spring 1817 was cold and sunless. It was also dry. Great heat was experienced from 19 to 25 June across the UK, an event that was subsequently remembered among Orion's 'remarkable phenomena'. However, at the end of July the weather turned very wet and remained so through August and into September, once again spoiling hay and corn crops. The failure of the harvest meant that 1817 was 'a period of famine for virtually all North Wales and, while popular disturbances seldom duplicated the events in Amlwch[10], violence and social protest became endemic' (Post 1977, 72). October and November were dominated by high pressure and fine weather. December was stormy with some resultant flooding.

High winds characterised the start of 1818 with a severe gale on 14–15 January and winds to gale or hurricane strength across much of the UK between 4 and 8 March, as the *Hereford Journal* reported:

> … the upper part of one of the pinnacles of the cathedral was thrown down – the chimnies [sic] of the Kings Head inn & of Mr Newton in the High Street were blown down … in all directions through the county trees of the largest dimensions were torn up by the roots or stripped of their finest branches, the orchards suffered severely …
>
> HeRO, BG99/3/4

By the second week of April many places were cut off as floods became widespread, though June and July were hot and dry and for some the summer of 1818 was the longest, driest and warmest in living memory. By August, drought had been declared in an event that became a 'benchmark' against which to assess the drought of 1868. Whistlecraft's *Weather Almanac* would later report on a good crop of wheat as the outcome of the shower-free harvest.

While the second decade of the century has been recognised as being cold and wet, this period was also one of numerous localised extreme weather events. These events acted cumulatively, and in combination with prevailing socio-economic circumstances, to challenge the wellbeing of most cross sections of society but especially the poorest sectors. 'For the people who lived through these events – especially those to whom it seemed the summer had never come at all – autumn [1816] was not the end' (Munger 2014, 43–4).

Contextualising the 'year without summer'

The magnitude, timing and geography of the impacts of large volcanic eruptions on climate and society are still not fully understood. Discriminating between weather effects linked to volcanic events, and the natural variability of the climate is fraught with difficulty. Disentangling the event-related socio-economic and ecological implications from ongoing changes in the historical record is problematic. It is perhaps not surprising that after almost two centuries, the 'year without summer', long held to be an upshot of the eruption of Tambora, is facing renewed scrutiny.

This paper has explored the weather of 1816 within the UK and at the local level, but contextualised within a longer period of weather anomalies and a prolonged episode of societal hardship and upheaval between 1809 and 1818. The archival sources present a narrative for summer 1816 in the UK that supports existing literature: cold, very wet and sunless with frequent strong winds and storms. More importantly, they provide a detailed picture of the timing, geography and magnitude of specific extreme weather events within the year 1816 and throughout the period 1809–18. This is a timeframe that incorporates some very notable and well documented anomalously cold seasons, including the record breaking winter of 1813–14 (Manley 1947; Smith 1979).

For extreme events during 1816 we might single out the severe winter with periods of flooding (5–6 January) and heavy snow (6–8 February); heavy rain and flooding on 7 and 15 April; a very cold spring with snow on 12 May; and a very wet and cold summer interspersed with high-amplitude storm events. One may conjecture whether these conditions

were a function of normal weather, or of volcanic aerosols which would have produced a marked drop in surface pressure across the mid latitudes across the North Atlantic (Keyye *et al*. 1984, cited in Rampino *et al*. 1988, 84). Interpreting documentary sources of the type we have drawn upon in this research is an inherently subjective exercise, but we would argue that, despite the long run of generally cold wet conditions experienced in the 1810s, extreme weather recorded in the spring, summer and autumn months of 1816 may have been 'truly exceptional' and 'of a degree for which it is reasonable to invoke an external forcing mechanism' (Sadler and Grattan 1999, 187).

Our sources also add further evidence in support of 1816 being a difficult year for many people across the UK. In Upper Annandale (Dumfries and Galloway), the correspondent to the *Farmer's Magazine* (17, 483) described a year 'having neither spring, nor summer, nor harvest' and our sources too emphasise the need to recognise a sequence of unusual weather, most of it unfavourable for agriculture, within 1816. The weather hampered agricultural (and other outdoor) work, and harvests of grass, grain and vegetables were of poor quality and quantity. There was a shortage of fodder and livestock was lost in floods or heavy snowfall in some places. Storms and floods uprooted trees, and damaged homes and other buildings. Normal routines were disrupted and travel difficult. An impact on physical and emotional wellbeing is also inferred.

It is important to situate these disruptions in the social, economic and political context within which they occurred. In 1816 society was facing severe hardship and food shortages as a result of the war years (Oppenheimer 2003), and the economy was stagnating as over 400 000 men from the armed services entered the labour market and the country failed to recapture European markets (Post 1977). 'The coincidence of agriculture and industrial depression made 1815–16 one of the most difficult periods in the history of the British economy' (Rostow 1953, cited in Wood 1965). It is thus very difficult to disentangle the specific weather and related effects of Tambora from the context of ongoing calamity in which it took place. As Grattan (2006, 16) concludes, 'The influences volcanic eruptions bring to bear on peoples and cultures must be seen operating within a system which may contain pre-existing vulnerabilities, which can be social and economic as well as climatic.' The sequential extremes experienced during the so-called 'year without summer' exacerbated an already heightened level societal vulnerability – and represented something of a 'tipping point' against a backdrop of prolonged weather – and war-related hardship.

The context in which Tambora took place represents something of a special case and 'its circumstances cannot be immediately generalized' (Stothers 1999, 714). The example of the UK experience of the 'year without summer' presented here, however, does illustrate the value of positioning volcanic events and associated weather anomalies within a more focused local, and yet extended temporal context. Piecing together fragmentary and subjective sources has allowed us to create a detailed, geographically referenced and personal reconstruction of the weather, its impacts and the societal response, adding specifics to the all too often generalised weather narratives of this time.

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Notes

1 The anniversary was marked by a festival on Sumbawa; the International Conference on Volcanoes, Climate and Society at the University of Bern, Switzerland (Brönnimann *et al*. 2015); a BBC Radio 4 programme *High explosive: the Tambora story*; and numerous articles online and in press including 'Volcanoes and climate: after Tambora' in *The Economist* (2015). New books include D'Arcy Wood (2014) and Behringer (2015).

2 Oppenheimer (2015) critiques proposed connections between Tambora and the invention of the bicycle; shifts to more profitable opium production in China; and an interest among the British in navigating the Northwest Passage. Others have suggested Tambora might have even been responsible for Napoleon's defeat at the battle of Waterloo (McWilliam 1996).

3 An example visualisation by Philip Brohan is https://vimeo.com/120792719

4 We concentrate on the 10-year period 1809–18 so as to include possible effects of the 'unknown' eruption of 1808/9 (Guevara-Murua *et al*. 2014) and interesting weather events of that year in the UK.

5 All archival sources are identified in the text using abbreviations explained in the caption of Table 1. Further detail is available in the supplementary material available online (Table S1).
6 St Mary's is the oldest religious foundation in the City of Nottingham. The church ran a workhouse in the city from 1726 until 1834 when responsibility for workhouses was transferred from parishes to Boards of Guardians.
7 There are few weather references within *Agricultural state of the kingdom in February, March and April 1816* but those present emphasise that extreme weather and difficulty were experienced long before the summer.
8 Loaf of bread weighing four pounds.
9 *l* indicates pounds sterling.
10 The failure of much of the corn harvest in 1817, and the continued export of what grain there was to England led to riots in Amlwch, Anglesey, and the stealing of the rudder of the corn ship *The Wellington* (Jones 1966).

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1 Extreme weather events in the UK, 1809–1818.