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# Dealing with the deluge of historical weather data: the example of the TEMPEST database

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People have long been interested in the history of weather, particularly extremes, and chronologies of past events drawing on information from written records have been compiled and published throughout history. In recent years, concern over current and future weather and climate has triggered a new level of interest in past weather events and their impacts. This interest, alongside the development of digital humanities research methods, has resulted in a rapid growth in the number of online databases relating to historic weather and climate around the world. This paper documents the design, creation and content of one such database, TEMPEST, an online repository for extreme weather history in the UK. TEMPEST has been created as the major output of the AHRC funded project 'Spaces of Experience and Horizons of Expectation: The Implications of Extreme Weather in the UK, Past, Present and Future' (2013-2017). Unlike the majority of existing databases that rely on published materials, TEMPEST's records are drawn from primary research into original documentary sources held in archives around the UK. The c. 18,000 records that TEMPEST currently contains offer personalised and geo-referenced insights into the relationship between society and extreme weather in the UK spanning a period of over 400 years. In this paper we outline potential applications for TEMPEST and suggest directions for future research and resources in historical weather. We also consider broader issues for the digital humanities relating to the storage, archiving, ownership, and usage of data and the need to ensure connectivity between complementary datasets.

**Key words** extreme weather; weather history; database; digital humanities; archive; UK

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## Weather and the digital humanities

Technological innovation in the storage and retrieval of information, as well as increasing emphasis on making academic research accessible to the general public through open access policies, has facilitated the transformation of historical weather data into digital forms

(Black and Law 2004). In a parallel development, an increasing number of original records containing information on the weather are being digitised. The availability of historical newspapers online has transformed historical research on weather, with millions of pages of text now easily searchable for 'weather words'. For example, Welsh Newspapers Online by the

National Library of Wales (NLW) provides new opportunities for investigating past weather and its impacts (NLW 2017a). To date, 15 million articles have been digitised covering the period from 1804 to 1919. The open access platform and searchable interface means relevant material can be accessed much more readily.

Historical diaries detailing daily weather are also now available to read online, such as those of Isaac Butler whose observations in Dublin span the period from 1716 to 1734 (Dublin City Council 2017). Two surviving volumes of diaries kept by William Bulkeley of Anglesey, Wales, covering 1730–43 and 1747–60, have been digitised (Bangor University 2017) and subsequently transcribed by a collaborative project with Llên Natur. The daily weather observations were integral to the Bulkeley diary narrative and indeed were a key motivation for digitising the volumes. Other sources include the diary of Edward Williams and multiple almanacs that appear on the NLW flickr site (NLW 2017b).

Such developments are part of a more general growth of digital outputs, with online databases becoming an increasingly popular output from academic projects across the arts and humanities (Brewster 2006; Hall *et al.* 2014; Sykes *et al.* 2013). ‘Digital Transformations’ have been identified as a priority area by the UK’s Arts and Humanities Research Council (AHRC), and it has been argued that ‘digital technologies are changing the ways humanities scholars think’ (Hayles 2012, 42). Databases specifically allow previously fragmentary and dispersed data to be united in one place. They also offer the possibility of uniting qualitative and quantitative data (DeLyser and Sui 2013).

New challenges, however, have also accompanied this digital turn. There are concerns over the long-term access to the resources, security of data, and the removal of the data from its original archival context. As Crang (2015, 357) noted:

Digital media shift attention from stocks of information (in archives and libraries which people may choose to visit) to flows of information (even if people try and ignore them) ... there is a challenge from digital humanities to reconcile the elaboration of meaning from a specific body of material and the reduction of a massive corpus to a pattern.

In this paper we document the design, creation and content of our research database, TEMPEST (Tracking Extremes of Meteorological Phenomena Experienced in Space and Time), an online repository for narrative sources on historical extreme weather events in the UK, as well as considering key issues for the digital humanities. As academic researchers, how can we ensure that our database outputs continue to function as technology changes and as research teams move on to new projects and new institutions? How are such

public facing and labour intensive resources valued, particularly in comparison to more traditional paper outputs? How can we ensure that researchers are fully credited in any future use of the data? Should academics be better trained or supported in the design and maintenance of database and digital technologies? Finally, thinking specifically about the global nature of the subject of our database – weather – does more need to be done to encourage compatibility between thematically connected datasets, perhaps in the form of collaborative or virtual research environments (CREs and VREs)? (see Buddenbohm *et al.* 2014; Keraminiyage *et al.* 2009). We return to some of these questions below.

We first review materials available for weather history in the UK, and previous attempts to write histories of the weather. We then provide a review of a selection of online weather databases before detailing the design, content, and possible applications of TEMPEST.

## Historical weather in the UK

There is a tremendous amount of information available in archives, libraries and online for anyone interested in historical weather. In the UK this includes a large archive of instrumental data produced by national bodies like the UK Meteorological Office, as well as by independent observers and enthusiast organisations, which can be used to tell us about past temperature, rainfall, pressure, wind strength and direction, hours of sunshine, and to reconstruct daily weather patterns for the past hundred or so years. Older instrumental data, largely found in private meteorological diaries, has also been subject to sustained analysis by climatologists. For instance, Gordon Manley assembled the Central England Temperature (CET) series of monthly mean temperatures, stretching back to 1659 (with daily readings from 1772), from hundreds of fragmentary sources (Manley 1953 1974). The CET is one of the longest continuous instrumental surface temperature series available globally [the Central European Temperature Series compiled by Dobrovolný *et al.* (2010) is slightly longer, with monthly data to 1500 and daily data to 1760] and is based directly on thermometer readings drawn from various sites forming an approximately triangular area, enclosed by Bristol, Lancashire and London. Now maintained and updated by the Hadley Centre (Karoly and Stott 2006) the CET is used to calibrate proxy records of climatic change and represents one of the most studied climate records in the world (Jones and Hulme 1997). The England and Wales Precipitation series begins in 1766, also making it the longest instrumental series of its kind in the world (Wigley *et al.* 1984; Alexander and Jones 2001) and indicating the richness of the UK record. Hubert Lamb

worked extensively with the UK Meteorological Office's historic pressure data, reconstructing monthly barometric pressure maps for the North Atlantic and Europe back to 1750, from which he was able to identify changes in atmospheric pressure and wind patterns from year to year. Historic instrumental observations were also key to developing his assessment of the impact of the world's volcanic eruptions on weather and climate since 1500 (Lamb 1970). More recently, the collection and digitisation of historic pressure data from private diaries as well as from ships logbooks, has been the focus of a number of Met Office projects through the Atmospheric Circulation Reconstructions over the Earth (ACRE) initiative (Allan *et al.* 2016).

Whilst providing a valuable tool for comparing past and present climate conditions and for exploring future climate through modelling, instrumental data tell us very little about what the weather was like for those who lived through it, how it affected people and how they responded. It is also increasingly unreliable the further back in time we go. The focus of this paper, therefore, is on narrative sources that detail the relationship between people and their weather.

### Compilation and chronology

The earliest records of weather tend to focus on 'meteoric' weather – the unusual or extreme event that disrupted everyday life at the local level (Jankovic 2000; Golinski 2001; Naylor 2006). From the early eighteenth century, extreme weather events were regularly included within broader lists of remarkable occurrences in local, regional or national history and published in almanacs and diaries. Although the gradual professionalisation of meteorology in the second half of the nineteenth century saw a shift towards more systematic investigation of weather using standardised instruments, interest in extreme events endures.

Published chronologies represent concerted efforts to produce comprehensive national weather, hydrological or storm histories. These include: Thomas Short's *A general chronological history of the air, weather, seasons, meteors, &c* (1749) and *A comparative history of the increase and decrease of mankind in England ... to which is added a syllabus of the general states of health, air, seasons, and food for the last three hundred years* (1767), a source Lawrence (1997, 145) describes as, 'a uniquely long and early weather chronology, based on old diaries ... centred on Suffolk'; Edward Joseph Lowe's *Natural Phenomena and Chronology of the Seasons* (1870), a volume that covers the period 220 to 1753 and includes information from parish registers, county histories, periodicals and newspapers, and which he intended to extend to a further two parts as well as a separate volume for 'foreign countries' but these do not

seem to have appeared; C.E.P. Brooks and J. Glaspoole's *British floods and droughts* (1928); C.E. Britton's *A meteorological chronology to AD1450* (1937); and H. Lamb and K. Frydendahl's *Historic storms of the North Sea, British Isles and Northwest Europe* (1991). From the nineteenth century, there are also examples of published lists of notable events and weather at the county scale, including volumes like the Nottingham date book (Sutton 1852), illustrating the importance of weather on local history. However, the reliability of early compilations of the weather can be challenging to verify as sources and materials are rarely identified or cited clearly and transcriptions vary (see Bell and Ogilvie 1978).

### Online weather databases

Before detailing the data, and the design and functionality of TEMPEST, it is useful to provide a short overview of a small number of pre-existing online weather databases. Owing to the geographical focus of our research, the majority of these are drawn from the UK and Europe. Other examples may be found on online resources (i.e. HistoricalClimatology.com 2017) or in the *Geoscience Data Journal*, a publication that provides an open access platform for the publication of scientific data.

### Chronology of British Hydrological Events (CBHE)

The focus of the British Hydrological Society's online searchable resource is on historic hydrology and the past behaviour of British rivers, with an emphasis on narratives of floods, drought, rainfall and unusual events that complement existing instrumental records. The database draws on material from *British Rainfall* (published 1860–1991) and the *Annual Register* (an annual survey of European and world events from a British perspective, published 1758–1946) (Black and Law 2004). To be included, each weather datum must incorporate:

- (a) specific information regarding a hydrological event, preferably using a source quotation; (b) source reference, allowing the original information to be located; (c) date information (at least the year of occurrence – up to the cut off year of 1937<sup>1</sup>); and (d) geographical reference (at least the main river basin)' (Black and Law 2004, 238)

There is full public access to the database 'for the purposes of searching existing information and for adding new records' (Black and Law 2004, 239), and no password system was included in the original design, launched in 1998. The revised website (2016) maintains the free search facility, but those wishing to add materials to the database are required to register. Acceptable forms of evidence include 'contemporary newspaper reports, published diaries and accounts of major events, and field observations of flood or drought

markers' (British Hydrological Society 2017). Users can search by geographical area or water body, event type, or date (Black and Law 2004). The value of the database 'lies in bringing together information from disparate sources, allowing users to swiftly search its contents spatially or by time, allowing access to information held in the database, and providing reference to original source materials which the user may wish to consult' (Black and Law 2004, 245). Moreover, 'as more entries are added to the chronology, the more they confirm, and qualify, earlier entries, enhancing user confidence' (Black and Law 2004, 245). During the web interface revisions undertaken in 2016, a geospatial component was added to the database, and contributors are encouraged to enter coordinates for site-specific entries. As of May 2016 the CBHE contained approximately 8000 accounts, with the potential for image uploading also under consideration.

*Climatological Database for the World's Oceans: 1750–1850 (CLIWOC), and UK Colonial Registers and Royal Naval Logbooks: making the past available for the future (CORRAL)*

The EU-funded CLIWOC project (CLIWOC 2017) offers an appreciation of ships' logbooks as historical resource and during the project the 'methods of handling and managing the wealth of weather information that they contain was firmly established' (Wheeler et al. 2006). The original project aimed at achieving 'data density' and therefore covered the period 1750–1854 and the world's oceans, using logbooks from English, Spanish, Dutch and French ships, generally found in national archives and libraries (Garcia-Herrera et al. 2005). The team also developed a 'dictionary' to 'translate the archaic wind force terms from the four languages into Beaufort equivalents' (Garcia-Herrera et al. 2005, 2). In a later extension, data from 6000 logbooks (of 120,000 available) from ships belonging to the Hudson's Bay Company were incorporated, selected as, owing to their Arctic voyages, these contained references to sea ice and icebergs (in the period 1750–1850) that were deemed to be of particular interest to those studying global climatic change. The 'hand written documents' mean that 'abstraction is necessarily manual and time-consuming' (Ayre et al. 2015, 57). Once abstracted, the team were able to move from narrative to number as the 'inherent homogeneity' of logbook entries allows for the original data to be presented in 'index' form on an ordinal scale (Ayre et al. 2015, 57). All of the data, in raw and processed forms, are available online and 'the team has engaged with the growing recognition of the need to share climate data and information' (Ayre et al. 2015, 60), meaning that 'current and future workers can trace the development of the database from its inception to its conclusion' (Ayre et al. 2015, 61).

The linked JISC funded CORRAL project (2008–9) imaged UK Colonial Registers and Royal Navy Logbooks, and transcribed the weather observations from a selection of the ships' logs as well as lighthouse records from the Caribbean, South Atlantic and tropical Pacific (CORRAL 2017).

*Old Weather*

Launched in 2010, this popular 'Zooniverse' project<sup>2</sup> draws on crowd sourcing power to abstract weather data from another collection of ships' logbooks (Old Weather 2017). Of some 4000 East India Company (EIC) ships' logbooks held in the British Library (Brohan et al. 2012), 891 were selected for digitisation (covering the period 1789–1834). The resulting 140,000 digital images 'were indexed and stored in the electronic media archive of the US Climate Database Modernisation Program (CDMP), which is managed by the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC)' (Brohan et al. 2012, 1553), which also managed the transcription process. The logbooks 'recorded elements to a basic standard that can easily be understood today', though there have been challenges linked to the age of the documents, including legibility, irregular format and 'frequent and variable abbreviations' (Brohan et al. 2012, 1554). The project won the Royal Meteorological Society IBM award for 'Meteorological Innovation that Matters' in 2013, and offers 'an unprecedentedly detailed view of the weather and climate of the late eighteenth and early nineteenth centuries' (Brohan et al. 2012, 1551). An extension to the project focuses on logs from whaling ships and the US Navy and Coast Guard voyages in the Arctic.

*Tywyddiadur, Llên Natur*

The Tywyddiadur database has been developed by Llên Natur, a sub-group of the Cymdeithas Edward Llwyd that was formed in 2009 to collate information on all aspects of the natural environment in Welsh, principally but not exclusively, in Wales (Llên Natur 2017). A key aim involved 'bringing Welsh language sources into the mainstream of information and research into climate in Wales and Europe' (Brown and Elias 2014, 29). The Tywyddiadur project, led by Duncan Brown and Twm Elias, is supported by a number of volunteers who transcribe and enter data. Tywyddiadur is a combination of the Welsh words Tywydd (weather) and Geiriadur (dictionary). The database includes entries on all aspects of historical weather and phenology. The interface is in Welsh, but all records are entered into the database in their original language. The Tywyddiadur database currently contains c. 106,500 entries, including the weather observations from the William Bulkeley diaries (see above). An important contribution of the Tywyddiadur project is the transcription of



weather information from a number of diaries held in private family collections, which would otherwise not be available for consultation. References to original source material are generally made and some entries are geo-referenced. The database is searchable by date and keyword.

### *EURO-CLIMHIST*

The original EURO-CLIMHIST comprised 30,000 pieces of proxy data from documentary sources for the period 1000–1525 from Germany, France, Italy, Switzerland and Austria, and was used to create estimates of temperature and precipitation. The approach attempted to:

bridge the gap between climatic history and weather history... providing a combined record which includes both the quantitative estimates of temperature and precipitation needed by the scientist, the economist, and the policy maker, and the detailed weather account, needed by the historian for his reconstruction of the past (Schwarz-Zanetti *et al.* 1992, 193).

The team coded their 'weather history' and also converted the data into monthly numerical precipitation and temperature indices, building on the original system developed by pioneer Bern-based climate historian Christian Pfister (1981). Non-contemporary or second-hand evidence was included 'wherever it contributed to the understanding of known weather patterns and its lower quality clearly marked' (Schwarz-Zanetti *et al.* 1992, 196). The team recognised the development of mapped results as an important next step.

Re-launched in 2015, Euro-Climhist (v.2) is based initially on data relating to weather and climate in Switzerland (1500–1999), with plans to add further 'modules' relating to other countries in Europe from 1500 and at a European level from 1000 to 1500. Groups working on regional and countrywide climate histories are encouraged to publish their databases through the Euro-Climhist system (EURO-CLIMHIST 2017). The database is available in German, French, Italian and English and at present there are 155,000 records in the Switzerland module covering early instrumental observations, documentary data and proxy data, weighted towards Northeastern Switzerland and the period 1700–1850. Users can search by data category, time period and place. The emphasis here is on combining instrumental and phenological data series, which have, in the main, been previously published elsewhere by Christian Pfister and other researchers at the Oeschger Centre for Climate Change Research at the University of Bern over the last 40 years. The wider website also provides a useful overview of historical climatology sources and methods, strictly distinguishing between

contemporary and non-contemporary observations, and highlighting the value that results from combining data of different types and from different authors and places.

### *Tambora.org*

This is a climate and environmental history CRE focusing on climate reconstruction, environmental change, and the impacts of weather and climate including the coping strategies of impacted societies (Riemann *et al.* 2015; Tambora.org 2017). The research team describe databases as 'important tools to store data and provide access for a broader community offering new dimensions of scientific elaboration of the data' (Riemann *et al.* 2015, 66), but suggest that a move towards CREs or VREs is required to bring together and share data, standardise the structure of those data to ensure comparability, and to ensure their long-term sustainability, and public accessibility. This would be a particularly beneficial move for the necessarily interdisciplinary and collaborative historical climatology and environmental history research fields, by providing 'the necessary infrastructures and tools to support the workflow to transform raw data into useful and relevant information' (Riemann *et al.* 2015, 63). As a database of original text quotations, the CRE *tambora.org* facilitates the synopsis of information from different locations and in different original languages.

### *Atmospheric Circulation Reconstructions over the Earth, ACRE<sup>3</sup>*

The international and interdisciplinary ACRE initiative is a consortium of nine partner organisations including the UK Met Office that undertakes and facilitates the recovery of historical instrumental surface terrestrial and marine global weather observations to underpin weather reconstruction or reanalysis spanning the last 250 years (Allan *et al.* 2016; ACRE 2017). The data and reanalyses are freely available. To date, the emphasis has been on the collection of pressure data and ACRE has been an important actor in the creation of the International Surface Pressure Databank (ISPD) (Cram *et al.* 2015), but the ACRE team are involved in a very wide variety of historical climatology and data rescue projects globally (Allan *et al.* 2016).

### *Enthusiast databases*

Finally, there are a number of amateur and enthusiast organisations that place emphasis on the collection and archiving of weather data. In the UK, members of the Tornado and Storm Research Organisation (TORRO) collect data relating to extreme storm events in Europe through Severe Weather Report Forms. The Climatological Observers Link (COL) (likewise a number of European counterparts) was established in part to

enable the exchange of weather data between observers (Endfield and Morris 2012), though not the general public. There are also examples of sustained and accessible efforts in data compilation by individuals.

Compiled by Martin Rowley as an attempt to collect together in one place the most notable events in the weather history of the British Isles, *Booty Meteorological Information Source* (Rowley 2017) primarily draws on weather data within a number of key texts, including Lamb's *Climate, history and the modern world* (1982), and *Historic storms of the North Sea, British Isles and Northwest Europe* (1991), and Brooks and Glasspoole's *British floods and droughts* (1928). It is not strictly a searchable database, but instead a year-by-year directory of notable events from 4000 BC to 2014, with place references where available, classified as thermal, hydrological or storm events. It has been a useful source to check for published references to events that we have found documented in archives (see below).

## TEMPEST

### *Overview and design*

From the outset, one of the primary outputs of our AHRC-funded project 'Spaces of Experience and Horizons of Expectation: The Implications of Extreme Weather in the UK, Past, Present and Future' (2013–16) was to be a freely accessible online database resource. This brings together accounts of extreme weather extracted from documentary materials located in archival repositories within five case study regions across the UK (see below). Named TEMPEST (Tracking Extremes of Meteorological Phenomena Experienced in Space and Time), the resulting output (as of February 2017) contains c. 18,000 records of extreme weather events in the UK. While social and economic systems have generally evolved to accommodate some deviations from 'normal' weather conditions, this is rarely true of extremes. For this reason, such events can have the greatest and most immediate social and economic impact of all climate changes. We believe that the construction of regionally specific climatic histories and historical extreme weather events, and investigations of the memories of and social responses to these events are crucial for understanding the nature of the events that might take place in the future, and it is for this reason that our focus has been on extreme weather. TEMPEST is a shared resource and includes links to all institutions involved in the research (University of Nottingham, Aberystwyth University, University of Liverpool, and University of Glasgow). The homepage<sup>4</sup> summarises the project whilst tabs across the top provide access to the search form, results list and results map, and help pages. TEMPEST has a high level of search functionality and whilst weather type is the primary search subject, it is possible to also

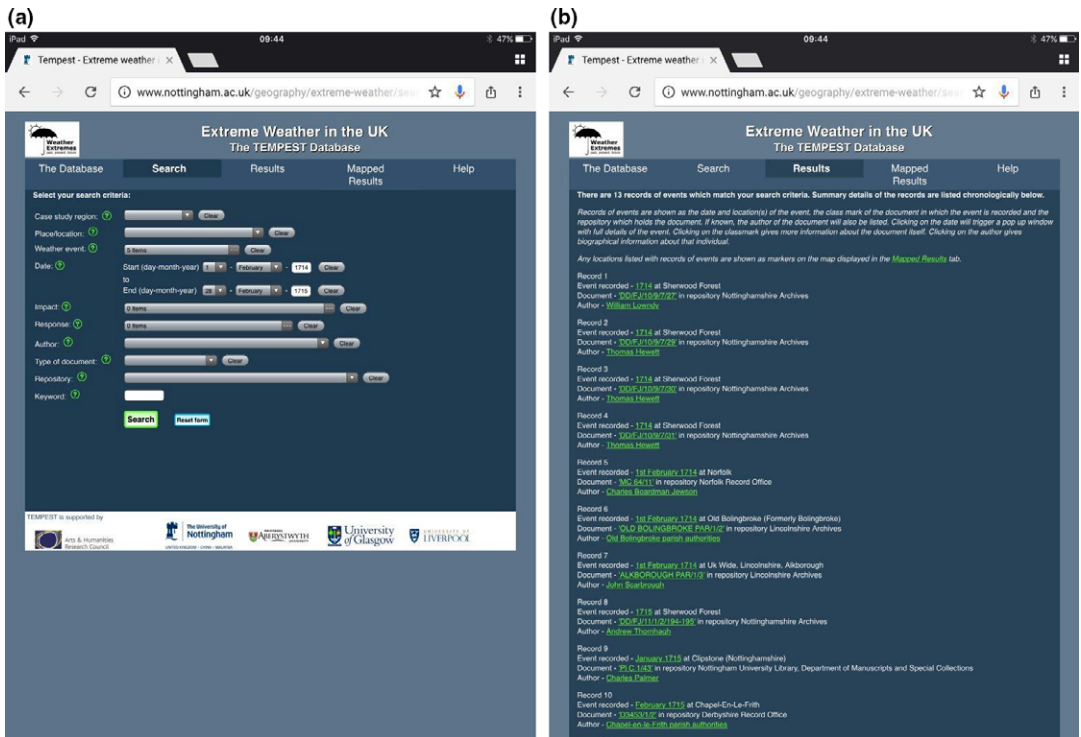
perform searches by place, date, author, document type or repository, or by the type of impact or response the weather event generated. Although not part of the original design, a keyword search option is also available. In order to limit the time taken to perform a keyword search, this uses only the content entered by the research team into the 'description of the event quotes' box in the admin application (see below).

The TEMPEST database and its associated web applications were designed, created and managed by Richard Tyler-Jones in consultation with the academic team on the project. The resource, which is a normalised database hosted by the MySQL relational database management system, was designed in accordance with relational principles and always with the public in mind. From hyperlinked text in the results list, the user can access the full record of a particular event, alongside details of the document and biographical author information where available (Figure 1). The entries are overwhelmingly text based but there are also a small number of visual sources (Figure 2).

Data were extracted from the original sources and entered into the database by the project team (comprising eight individuals) through an online form (admin application) that had a number of required fields (document reference and repository, type, date, place and weather type), as well as other optional fields. Each member of the project team has entered data and this, as well as the refinement of our method and the database fields as time has progressed, means that there are inevitably some inconsistencies within the data entry. Each member of the team was encouraged to discuss any queries they had relating to what should/should not be entered with the rest of the team, and several days were spent working together in the archives and looking at sources collaboratively. Errors are also to be expected given the volume of material, although summary views, automated and non-automated checks have helped to eliminate many of these. Owing to personal preference of certain members of the research team members, large batches of data from particular sources have been uploaded from Excel spreadsheets. These include school logbooks from the Outer Hebrides and the letters and diaries from the Llydsnam collection at the NLW.

### *Content*

*Temporal coverage* The earliest recorded extreme weather event we have entered into TEMPEST is a lengthy period of heavy rain and flooding on the river Trent in 1346, a secondary reference noted within a booklet on the Nottingham Flood Protection Scheme produced by the Trent River Authority in 1967. The most recent events are the floods of spring and autumn 2007 in the Wye Valley. TEMPEST thus

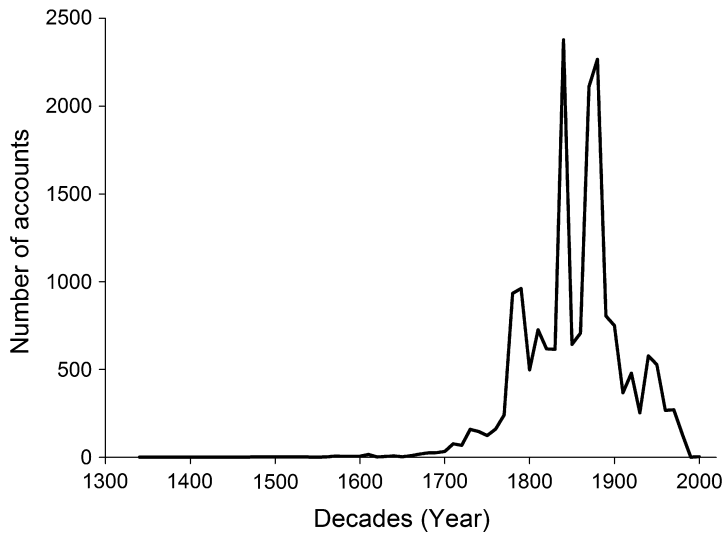


**Figure 1** Screenshots from TEMPEST: (a) the search page completed for a search for ‘all wind events’ between ‘1 February 1714 and 28 February 1715’ with all other fields left blank; (b) the results of that search for ‘all wind events’ between ‘1 February 1714 and 28 February 1715’



**Figure 2** An example of a visual source listed in TEMPEST. A photograph from a small album showing people skating, walking and cycling over the frozen River Trent in February 1895  
 Source: MS 258/3, University of Nottingham Manuscripts and Special Collections. This photograph documents the most recent occasion that the River Trent has been frozen over. The prolonged frost of winter 1895 was a national calamity but also provided opportunities for outdoor recreation





**Figure 3** Graph showing the distribution of extreme weather narratives within TEMPEST by decade

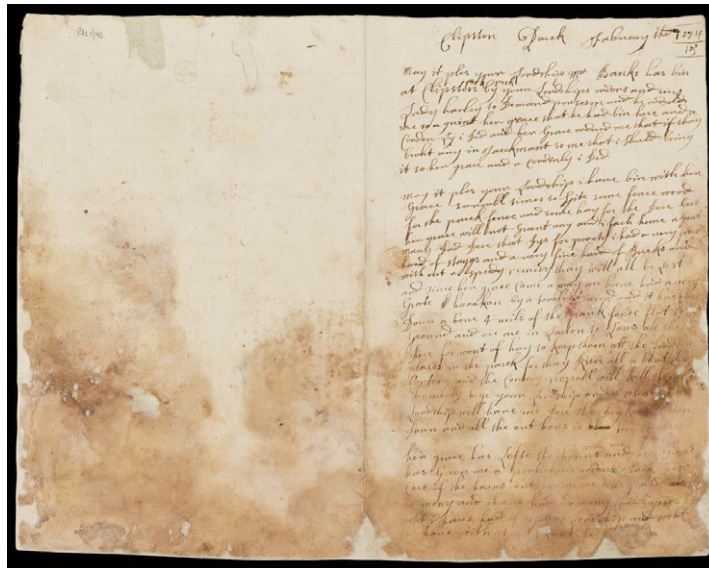


**Figure 4** Screenshot from TEMPEST displaying the results of a search for ‘all wind events’ between ‘1 February 1714 and 28 February 1715’ on a map. Each marker indicates an account of the event assigned to that location

spans a period of 661 years, although the vast majority of entries relate to the period between 1700 and 2000 (Figure 3). The temporal distribution of the data is a

product of the available data, the changing nature of weather record making and archiving, as well as our own research method. Particular sources (diaries) act to skew the data. For this reason, we would encourage caution in any attempt to use the database to determine any changes in the frequency of extreme weather events over time, though it may be possible to normalise the data to take levels of recording into account. In many cases the database contains multiple accounts of the same weather event but these have not been explicitly connected within the system – again this complicates any analysis of the temporal distribution. Although our study was far from a complete survey, it provides useful insight into the holdings of UK archives and cataloguing practices and it is starting to highlight the potential of a variety of materials for the investigation of climate and weather history hitherto little used for the purpose (Veale *et al.* 2017).

On entering an event, we have made a distinction between the date of the weather event and the date of the document’s creation. In many cases original documents were created shortly after the occurrence of the weather event to which they refer, but it is also relatively common to find references to much earlier events (as is the case with the 1346 event above), indeed the ‘benchmarking’ of earlier events (recalling earlier events of a similar type within accounts of contemporary events) was an area of investigation and relatively common practice with both flood and freeze events. Day of the week online calculators proved useful in calculating dates of occurrence when dated documents referred to an event having taken place, for example on ‘Tuesday instant’. Wherever possible, exact dates for both the timing of weather events and the



**Figure 5** Letter from Charles Palmer, Keeper of Clipstone Park, Nottinghamshire, to Edward Harley, Lord Harley, later 2nd Earl of Oxford, 1 February 1714–15

Source: Portland (London) Collection, PI C 1/43, University of Nottingham Manuscripts and Special Collections. Charles Palmer notes the occurrence of a 'very Grate harakan' that has blown down four miles of the park fence. As they can no longer keep the deer in one place, Palmer is worried that they may be poached

creation of source documents has been used, but there are many cases where only a partial date is available (the minimum required for an event to be included is a year). Conversely some of the narrative sources are very precise, giving timed observations. Triangulating sources or further research may help to improve the resolution of particular records but for the initial version of TEMPEST we have remained true to the information within the specific documents. The search facility enables users to search for weather events on specific dates or within date ranges and also to search for events occurring on a particular day in any year, for example Christmas Day, or periods and/or seasons in any year, for example from 1 June to 31 August (summer). The latter search is particularly useful for identifying unseasonable weather.

Defining the start and end dates of weather events has been more difficult, particularly with periods of unusually hot, cold, wet, dry or stormy weather recorded within daily records (diaries), or with slow onset thermal events. Each team member has used his/her experience in making these judgements and although independent references to the same event in the system go some way to addressing this issue, we would encourage users to interpret the start and end dates as a guide only.

In order to achieve the change from the Julian to Gregorian calendar, 11 days were omitted from the year 1752, that is, the day after the 2 September 1752 was 14

September, in accordance with the Calendar Act of 1751 (see Freiburg 2000; Poole 1995). Until September 1752, the New Year began on 25 March (Lady Day) but dual dating (the practice of writing two years when dating material between 1 January and 24 March – see Figure 5 for an example) was commonplace for many years before, adding a further layer of complication to events that took place from 1 January to 24 March, and making 1751 a short year running from 25 March to 31 December! Scotland had changed the start of the year to 1 January in 1600. Where documents are dual dated, we have used the Gregorian calendar date to enter the narrative into TEMPEST, providing further details in the notes section. Single dated pre-September 1752 material is catalogued using the date as it appears on the document and we would therefore advise users looking for accounts of particular events in this period to check multiple years and broaden searches, that is, for the 1 February 1715 wind event to search for any accounts of wind in February 1715 and February 1714 and then to eliminate irrelevant entries from the results list (illustrated in Figures 1 and 4).

*Geographical coverage* The key purpose of the project was to create a database that could be used to create spatially specific understandings of extreme weather events. The database enables the user to quickly see where multiple accounts of the same event, potentially written from different places, are present (Figure 4). Our search for materials was concentrated

in five case study regions, selected on the basis of previous research and the findings of the Department for Food, Environment and Rural Affairs' (DEFRA) *UK Climate Change Risk Assessment* (2012), in which each was recognised as being vulnerable to climate change and different types of extreme events: North, West and Southwest Wales; East Anglia Coast; North-west Scotland; Central England; Southwest England. Available source materials and personal research interests resulted in slight changes to these areas as the research progressed, North, West and Southwest Wales becoming 'Wales', and East Anglia Coast becoming 'East Anglia'. Regions have been difficult to define and judgments have tended to be made on the basis of available documentary material. Owing to the sheer volume of material that includes reference to weather either directly or indirectly, our investigation has not been exhaustive in any of the regions. We have prioritised materials that provide narrative detail on events and their impacts and responses, on documents that include reference to hitherto little discussed events or those that corroborate other events we have identified. Material relating to extreme weather in the UK but outside the boundaries of our case study regions has been attributed to an 'other' category. The geographical distribution of the TEMPEST data is thus concentrated within our case study regions, although broadly covers the UK (Northern Ireland is under-represented as no primary research was undertaken here) with a smaller number of entries for Ireland and mainland Europe. Within the case study regions, the geographical concentrations are the result of our research having been, out of necessity, targeted in key archives and collections, in the main Local Government Record Offices (and in the national archive held at the NLW).

As our aim was to explore situated accounts of extreme weather events and local impacts, all weather events in TEMPEST have at least one place reference assigned to them. These are taken direct from the source materials or catalogue information. In most cases they relate to villages, parishes, towns or cities but are sometimes more (large estate residencies for example), or less (counties, regions, coasts or rivers for example) specific. Wherever possible, place entries have been geo-referenced with decimal degree coordinates. This geo-referencing enables the results of database searches to be displayed on a map, and the user can also choose for all the records mentioning a specific place reference or attributed to a particular case study region to be displayed. As with dates, place references should be taken as a guide only, the potential for error arising from changing place names, boundaries and spellings, as well as mistakes or misinterpretation during transcription.

*Meteorological coverage* Our search encompassed the full range of extreme weather as experienced in the UK. Source material was in the main located through searches for key weather terms (weather, meteorology, storm/tornado/whirlwind, flood, drought, snow/frost, heatwave etc.) in online and paper catalogues. In entering the data onto TEMPEST, each account has been assigned to *at least* one weather type from a drop-down list (compiled during the design phase and refined as the project progressed), as detailed in the document, or that otherwise best fit. Underused weather terms were then removed and the entries reassigned to 'best fit' categories. Of a total 18,021 entries, the dominant weather types are rain (assigned to 5550 entries), cold/extreme cold (assigned to 3966 entries with 'freeze' a separate category) and snow (assigned to 3934 entries with 'snowstorm', 'snow shower', 'heavy snow', 'snow drift' and 'snow lying' all being separate categories). The number of entries relating to hot and dry weather are much smaller but no less informative (drought conditions – 221 entries, water scarcity – 88 entries, lack of rainfall – 553 entries, extreme heat – 460 entries and heatwave – 22 entries). There are a number of entries where no mention is made of any specific meteorological phenomena and for these cases we have also included more general categories of weather type that we have grouped under 'conditions'. Users should be wary about the changing language of the weather over time and should keep searches as broad as possible, for example reference to a 'hurricane of wind' does not always suggest wind speeds of what we would today recognise as hurricane strength.

Although archival research was structured through a search for events perceived at their time of occurrence as 'extreme', when transcribing information from original documents a very broad interpretation has been employed, meaning that many of the events may not necessarily be truly 'extreme' in nature. Conversely, events that seem fairly normal when read in isolation can, when collated with other accounts, indicate a potentially noteworthy spatially or temporally important event.

Where featured in the original documents, snippets of instrumental data have been included in the entries but we have not as yet attempted to link narrative accounts with instrumental data located elsewhere. Neither have we attempted any kind of indexing of the severity of the events, either meteorologically or according to their level of impact, although it is an avenue for future work. Respecting the biases that are present within the data, we have also resisted looking for patterns that might be suggestive of a changing climate. It should also be noted, however, that these biases themselves offer significant potential to explore how and why people considered events to be extreme

within particular temporal, spatial and socioeconomic contexts.

*Documents and authors* We did not set out to study any particular document type, but have instead been directed by catalogue searches (as detailed above). We have found ourselves consulting a very wide variety of documents (numbering 1788), with different genres or types dominating our resource in particular time periods, illustrative of the changing nature of the documentary weather record over time and perhaps also of broader trends in weather observation. The majority of event records (64%) come from diaries (that sometimes contain hundreds of individual event records). The next largest document type is correspondence of all types (7% of event records) (see Figure 5). Users can choose to search for weather events as detailed in particular document types, which have been categorised according to the type that seemed most appropriate. The majority are primary and contemporary records of the weather [sources characterised as ‘first class’ by historical climatologists like Christian Pfister, in Xoplaki *et al.* (2001, 591)], but some are later documents that refer back to earlier events and a small proportion are secondary materials, including for example, compilations of newspaper extracts. The full details of each document are provided, including the full reference, the repository where it can be consulted, the author, coverage dates and a brief description of content.

Basic author information has been included wherever possible for the 1084 named authors currently in TEMPEST. Biographical details have been taken from archive catalogues, published biographies or internet searches. Images of authors have been uploaded to the system where available. No further categorisation of the authors has been undertaken (i.e. male/female, class/status, profession, age at time of weather recording), though again this would provide an interesting avenue of future research. The database contains records created by some famous (and infamous) individuals and organisations, a reflection of the types of material that has survived and that has been considered worthy of preservation in the archive. Authors include one Queen (Elizabeth I), numerous Dukes and Duchesses (including several Dukes of Newcastle and Dukes of Portland), industrialists (the Galton and Cadbury families), Lords and other large landowners, MPs (William Banks, John Evelyn Denison, William Gladstone), famed artists (Laura Knight), musicians (Edward Elgar) and writers (D H Lawrence), as well as meteorologists (Edward Lowe). These famous figures may help to attract attention to TEMPEST, many of them not previously acknowledged as weather observers. This said, we have sought to include records from all types of people (farmers, land agents, clergymen, doctors and teachers are well represented groups) and would like to emphasise the value of records made by more ‘ordinary’ people,

particularly in areas not covered by existing instrumental series or other prior research. Seemingly ‘ordinary’ people often kept ‘extraordinary’ detailed and lengthy records of their lives and the place of weather within them. Two examples are included below for illustrative purposes.

One example is carpenter and brewer John Clifton of Oundle, Northamptonshire. Clifton’s ‘daybooks’ cover the period 1766–84 and, although they begin more like business diaries, they gradually include more references to social life and the weather as it affected his daily activity and wellbeing, as well as the local impacts and responses (also see Cartwright 1973). During the hard winter of 1767, Clifton records how, as an overseer of the poor, he:

set several poor men to work 2 days this week [10 January] to shovel a passage thro’ the snow in the streets to make a passage for waggons, carts, & all other things. I gave each of the men 1s a day & a pint (ZA 8734, Northamptonshire Record Office).

In the flooding that followed the freeze, Clifton’s daybook records the immediate risk to bridges and the death by drowning of a local boy. Very heavy snow again covered Oundle at Christmas 1783 and Clifton records an unusual impact on the natural world:

The wood labourers of Glassthorpe give the same account of the grains<sup>5</sup> being broke off the oak trees in the forests as our other men so in our little woods, & say that the day after Christmas Day it was very dangerous being under any of the oaks, the grains broke so fast, in all parts & made such a continual cracking that the noise was frightful to hear – they think there will be 100 load when they are gathered & brought out. This is one of the most uncommon events I ever heard of (ZA 8746, Northamptonshire Record Office).

Ruth Bourne’s diaries begin in January 1874 when she was just 8 years old and continue until her death in 1953. They thus provide a fascinating opportunity to explore the changing relationship between an individual and the weather almost over a complete lifetime. On 1 February 1945 Bourne writes:

The weather has been arctic for the last fortnight & the snow has lain thick on the ground. We had phenomenal degrees of frost – 2 nights there were 27 degrees of frost<sup>6</sup>: the roads were icy & dangerous – no one went out unless they had to for necessary shopping. I have been a prisoner to the house feeling wretchedly cold & achey & miserable; I have stayed in bed till 12 o’clock most days – & then for the rest of the day have sat by the dining room fire with a rug over my knees & glad to have a hot water bottle on my legs ... (AK22/82, Herefordshire Record Office).

*Notable extreme events covered by the database* The value of TEMPEST is in bringing together previously disparate and often previously unused documentary sources on UK weather history. Others have previously



used many of the documents we have consulted because of their value for other ends: local, family, medical, industrial or agricultural history for example, but their value for weather history has not in the main been acknowledged. By searching TEMPEST by weather type or time period, it is possible to quickly assess where multiple accounts of the same weather event, as recorded by different people, perhaps located in different places, have been captured (Figure 4), and also to ascertain whether a particular event entered the popular memory (i.e. if it is recalled by those living after its occurrence). Even single word or line entries in a diary, when combined with other sources, can help us to piece together the anatomy of particular events, whilst also allowing for control of more farfetched entries (Xoplaki et al. 2001, 590). TEMPEST adds new events to established chronologies of extreme weather in Britain, and provides the potential to reveal new, personalised and localised understandings of the relationships between extreme weather events, people and places. In order to illustrate this we have selected a few examples.

*The windstorm of 1 February 1715* is recorded in a number of parish registers as well as in other documents and the database has allowed us to bring these together. Parish registers can:

contain memoranda of particularly catastrophic or memorable events; important in some instances as the main source for otherwise little documented events that might be missing from existing weather event chronologies; and for others in detailing localised impacts. (Veale et al. 2017, 15)

At Old Bolingbroke, Lincolnshire, the incumbent recorded that there was ‘a remarkable storm of wind which according to common report blew down some thousands of houses in the Kingdom’ (OLD BOLINGBROKE PAR/1/2, Lincolnshire Archives). Fifty-five miles to the north at Alkborough the wind ‘blew down many thousand trees in Lincolnshire,’ a comparable windstorm event apparently not recalled in the ‘memory of any man living’ (ALKBOROUGH PAR/1/3, Lincolnshire Archives). At Rolleston, in neighbouring Nottinghamshire, it was noted that:

On wch day was such a violent tempest of wind as was never known in any man’s memory, it struck down two pinnacles from the steeple and did great damage to the Church and a good deal more in town (Rolleston PR, Nottinghamshire Archives).

The wind blew down a large quantity of trees in the Royal Forest at Sherwood (DD/FJ/11/1/2/194-5, Nottinghamshire Archives) and several miles of the park fence at Clipstone (PI C 1/43, University of Nottingham Manuscripts and Special Collections and Figure 5). Daniel Baker, resident in Buckinghamshire, received conflicting reports from his agent of the damage done by the windstorm to buildings and trees on his estates in

Edenthorpe and Fenwick, South Yorkshire. He was first notified of great damage estimated at £50 and then, in a later letter, a revised estimate of a loss of just 12 trees (Me C 12/4/8, University of Nottingham Manuscripts and Special Collections). In Derbyshire the wind blew the weathercock off the steeple at Chapel-en-le-Frith and an ash tree was uprooted in the churchyard whilst a number of houses were destroyed (D3453/1/2, Derbyshire Record Office) and at Ashbourne William Johnson was killed when a stable collapsed (D662/A/PI/1/7, Derbyshire Record Office). In Norfolk C B Jewson’s chronology of notable weather events lists ‘a great storm of wind from the west did much damage’ (MC 64/11, Norfolk Record Office).

*The summer of 1826* was the second warmest on record according to the Central England Temperature series (Manley 1974) and followed a hard winter. Across the East Midlands, water was scarce, crops were poor, and livestock were short of fodder. In a letter to his wife, William Cavendish Scott Bentinck (4th Duke of Portland) refers to the effects of the drought of the previous year at his Fullarton estate near Troon on the west coast of Scotland, noting that it has thrown some tenants into rent arrears that he fears they will never be able to pay (Pw H 1028, University of Nottingham Manuscripts and Special Collections). Elsewhere, John Evelyn Denison, a progressive landlord, interested in agricultural improvements and later President of the Royal Agricultural Society, refers to the effects of drought on his own farms as well as the Midland counties and throughout the world in his diary entries for June and July 1826 (Os 3 D 1, University of Nottingham Manuscripts and Special Collections). The hot and dry weather had a dramatic impact on crops. In the entry for 21 May, writing from Ossington, Nottinghamshire, he remarked:

There has been no rain to do any good since February & no rain at all since the beginning of April – the distress for want of it is very great – the meadows have been eaten down & there is no prospect of hay. I have let off the lake and had all the water meadows well soaked.

A letter from 2nd Viscount Sydney in London to John R. Townshend dated 28–29 June contains the lines:

... All sun shine here & boiling hot, so long a drought has not long been remembered. From Ireland they have no hay, no potatoes, cattle die from want of water. I am much too great a philosopher to grumble in England too at sun shine. It is cheering to see it & I enjoy it ... (THF/X/3/6/6/1-3, University of Nottingham Manuscripts and Special Collections).

In Lincolnshire, at Old Bolingbroke, a legal document details an agreement to let cattle wander freely on the highways until the drought ended (2 DAWSON/14, Lincolnshire Archives), whilst Batewood Dashwood was unwilling to even have his estate even seen as ‘the turf was as brown as the road’, even though he was



desirous to sell it (MISC DEP 109/132, Lincolnshire Archives). This was a summer that lived long in the memory. Looking back on his life, for Henry Winn of Fulleby, also Lincolnshire, it was the driest summer he could remember:

It was pitiful to see the poor cattle hungry and parched with thirst, ranging aimlessly about the burned pastures. Many died during the summer and autumn, and some were kept alive by being fed on leaves from the trees and even thatch from the building was used to keep them alive (WINN 5/3, Lincolnshire Archives).

Reverend Lea in Droitwich, Worcestershire recalled summer 1826 during the dry summer of 1864 (850DROIT-WICHSPA/1/a/iii, Worcestershire Archives).

### *Potential applications*

We anticipate that TEMPEST will have a broad audience: public, professional, and interdisciplinary academic. In particular, TEMPEST has a variety of potential educational uses. We are working alongside the Royal Geographical Society (with IBG) to develop 'teaching guides' so that teachers can use the database in an age appropriate way (initially focusing on the geography curriculum). We also anticipate interest in the database from the insurance sector and agricultural organisations. It may well be of value for anyone interested in investigating the character, geographical and temporal range, and impacts of particular extreme weather events, or in comparing events in terms of extent and impacts, in particular time periods or the broader weather history of the UK, as well as those more interested in the history of weather recording, meteorological understanding, or in the people and places featured.

TEMPEST broadens and consolidates our view of the value of documentary sources in piecing together extreme weather history. The weather is a secondary subject in the majority of the documents included, functioning as the backdrop for the detailing of daily life. On its own and isolated, a single sentence on the weather may not appear of great value, but, as the examples above illustrate, within TEMPEST, multiple sources detailing the same (and pre- and succeeding) event(s) can be easily brought together to give a more detailed picture and understanding of the relationship between extreme weather and society. The nature of extremes lend themselves in different ways to examination, whilst some events are spatially selective, in terms of flooded area or region damaged by a storm, other events may be more pervasive and/or had more extensive impacts. By consolidating records of such events, TEMPEST provides a means of exploring the anatomy of events and their associated impacts.

The content of TEMPEST and the research method employed to identify extreme weather event narratives

in the archives also tell us a great deal about the documentary history of the UK and particularly the collections of Local Government Record Offices in terms of the age and authorship of the documents, as well as cataloguing practice. By retaining direct links back to archives, we hope that TEMPEST will help to raise the profile of Local Government Record Office collections and awareness of the weather data that many documentary sources contain.

### **Digital futures: data deposition and archiving**

To ensure TEMPEST's security and longevity, we have deposited the data with the Centre for Environmental Data Analysis (CEDA) (Endfield *et al.* 2017), and backup versions are stored at each of the project's academic institutions. We are also pursuing opportunities for non-academic partners to host and develop the resource. It is however impossible to identify the full array of potential uses of data and likely changes in technology and as such, 'Future-proofing the data so that it is readable and understandable in future years remains a time consuming and difficult job' (Allan 2014, 1).

It is important to note the substantial effort that TEMPEST, alongside all other historic weather and other humanities databases, represents. Unfortunately, as Riemann *et al.* rightly highlight, it remains the case that much of the data produced by scientific research projects 'is poorly documented and/or stored in a non-sustainable manner', meaning that considerable research effort can be wasted 'because of ignorance of existing data' (2015, 63). We therefore need to work to ensure that they are not only well publicised and used but also that those who have compiled them are fully credited in any future use. To this end we have 'minted' a dataset digital object identifier (DOI) for TEMPEST and have provided guidance on the website as to how any usage should be referenced (Veale *et al.* 2017). We have emphasised the need to always retain the linkages to the original source materials and data context. A number of groups have been given priority access (project partner organisations) and a trial access completed as part of the exhibition 'Weather Extremes: Making and Breaking Records in Nottinghamshire' at the Weston Gallery, Lakeside Arts, Nottingham (16 December 2016–26 March 2017). The resource will, however, 'go live' in 2017.

Databases of historic weather are growing in number and already represent a vast digital resource:

Research groups around the world have created large data collections on climatic parameters such as temperature, precipitation, storms, floods, etc. from an extensive and varied body of documentary records with different regional and thematic foci (Riemann *et al.* 2015, 64).

However, these result from distinct projects and are often designed and presented in a variety of ways that are often incompatible. Collaborative Research Environments and integrated approaches like ACRE (Allan et al. 2016) and tambora.org are a step in the right direction in uniting these resources, and encouraging the sharing of expertise and experiences among the community of users. However, significant challenges remain and it remains to be seen whether organisations will step up to the ‘meteorological databank challenge’ (Thorne et al. 2017). The diverse, complex and often partial data of the humanities (in different formats and languages) can be difficult to unite but it would be hugely beneficial if we could combine effort and systems. The expansive dataset within TEMPEST (a very small fraction of what is available for the UK) itself illustrates the great potential that comes from bringing sources together.

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## Notes

- 1 Chosen largely to ensure adherence to copyright law for published materials.
- 2 Zooniverse represents the world’s largest and most popular platform for volunteer-based research ([www.zooniverse.org/](http://www.zooniverse.org/)) Accessed 17 February 2017.
- 3 We are grateful for the support of the ACRE team in the development of the TEMPEST database.
- 4 <http://www.nottingham.ac.uk/geography/extreme-weather/search/> Accessed 17 February 2017.
- 5 Cartwright (1973) notes that the use of the term ‘grains’ probably refers simply to boughs or branches.
- 6 A degree of frost is a non-standard measure of air temperature indicating degrees (in this case Fahrenheit) below freezing.

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