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An historical analysis of drought in England and Wales

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Abstract This paper presents a chronology of drought in England and Wales from 1800 to the present day. It demonstrates how documented historical evidence of drought impact and synthetic flow series can be used to augment limited observed data and extend the period over which natural climate variability can be investigated. Rainfall deficiency analyses, seasonal partitioning of rainfall and an Aridity Index are presented to assess the relative severity of each event and examine long-term trends in drought frequency and magnitude. Over 30 important droughts were identified over the 200 year period, with a repeated tendency for dry years to cluster together to create multi-year droughts (e.g. 1798–1805, 1890–1909). Many predate observed hydrological data, leading to possible underestimation of drought risk. No compelling trends of increasing drought frequency or magnitude were found, although winter and summer rainfall showed marked spatial and temporal differences across England.

Key words drought; drought impact; historical analyses; BHS *Chronology*; deficiency; water resources; England and Wales

INTRODUCTION

A series of recent droughts in England and Wales has highlighted the UK's continuing vulnerability to this natural hazard and raises once again the issue of whether these events reflect climate change or natural climate variability. It is therefore vital that recent events are not viewed in isolation, but in the context of as long an historical record as possible. Droughts are multifaceted both in their meteorological character and range of impacts and there are many difficulties in quantifying a phenomenon which varies widely in its areal extent, duration and intensity (Tallaksen & van Lanen, 2004). This paper combines evidence from many sources, including the different, if overlapping, impacts associated with: meteorological drought – deficiency in rainfall; hydrological drought – accumulated deficiencies in runoff and aquifer recharge; and socio-economic drought – where the focus is on human impacts.

DATA SOURCES

In a global context the UK has a rich legacy of lengthy hydrometeorological records. However, raingauge coverage was poor prior to the 1850s and few river and groundwater level records exceed 100 years in length (Lees, 1987). In this historical review, observed hydrological data from the UK National River Flow Archive at CEH Wallingford, was augmented by extended synthetic runoff series, derived by the Climatic Research Unit (Jones *et al.*, 2003) from long-term rainfall and temperature series, and documentary evidence of drought impact. Observed data included long-term monthly catchment rainfall, river flow and groundwater level time series (from the British Geological Survey) and Chalk spring flows dating back to 1841 (Bayliss *et al.*, 2004). Documentary evidence of impact was obtained from the British Hydrological Society (BHS) *Chronology of British Hydrological Events* (http://www.dundee.ac.uk/geography/cbhe) and published drought review papers. The *Chronology*, launched in 1999, is an exceptionally valuable compilation of historical material (mostly pre-1935) drawn from wide-ranging sources. Although the extracts are often anecdotal and local in nature, they provide useful support when observed or synthetic data is limited.

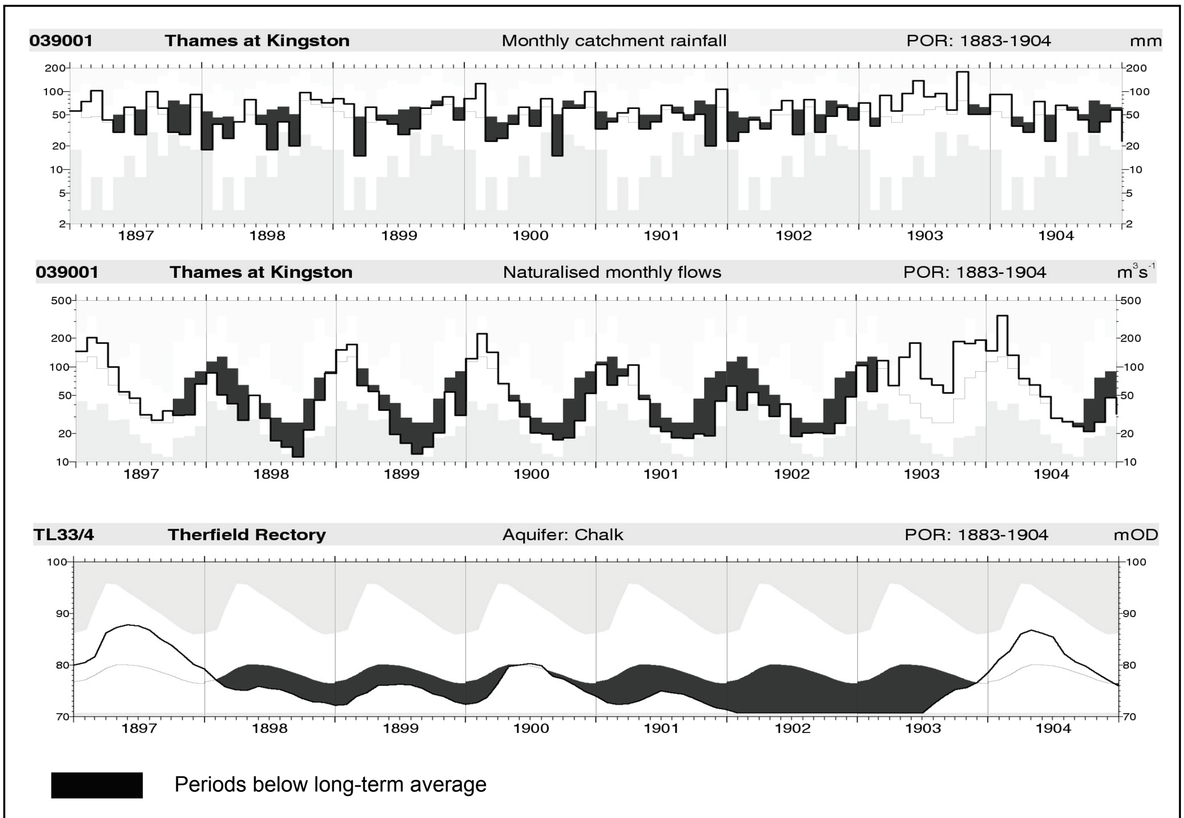
IDENTIFYING DROUGHTS

Relatively simple indices based upon accumulated departures of monthly rainfall or runoff totals (e.g. Bryant *et al.*, 1994) have been shown to be useful in identifying drought events. This study used ranked rainfall and runoff deficiencies (departures from the long-term average) over a range of time scales as a primary identification tool (see Table 1). Short (4–6 month) intense rainfall deficiencies can threaten water supplies in areas dependent on surface water (e.g. northern England in 1984 and 1995), while for groundwater catchments, deficiencies over 18 months or longer pose the greatest threat (Marsh & Turton, 1996). Droughts identified as important at a national scale may not impact at the catchment scale if the most intense phase does not correspond to the critical period for water resources provision (Table 1). These indices were supported by visual appraisal of long hydrological time series – plotted with periods of rainfall or runoff deficiency highlighted.

Table 1 Ranked *n*-month rainfall deficiencies and runoff deficiencies to identify droughts[a].

Rank	Max. 6-month rainfall deficiencies for England & Wales	Max. 24-month rainfall deficiencies for England & Wales	Max. 6-month runoff deficiencies[b] – River Eden (surface water catchment)	Max. 18-month runoff deficiencies[b] – Great Ouse (groundwater catchment)
1	1921	1855	Sep 1995	Nov 1803
2	1976	1997	Sep 1826	Nov 1934
3	1995	1934	Sep 1984	Oct 1922
4	1887	1803	Oct 1989	Nov 1991
5	1929	1992	Sep 1996	Nov 1815
6	1870	1922	Oct 1919	Oct 1944
7	1990	1845	Sep 1806	Oct 1997
8	1854	1889	Nov 1915	Oct 1894
9	1826	1976	Sep 1870	Nov 1973
10	1938	1807	Oct 1887	Nov 1902

[a] The years and months featured relate to the end of each deficiency period.
[b] Based on synthetic naturalized flow series (from CRU) 1801–2002.



Extracts from the BHS *Chronology*
1902 Hascombe, Guildford: "All the wells in the neighbourhood were lower than in living memory and many were dry due to the succession of years of deficient rain."
1902 December Abingdon: "springs were exceptionally low at the end, and the outlook was serious."

Fig. 1 Example of data and information sources for the Thames Basin 1897–1904, an intense phase in the 1890–1910 drought: monthly catchment rainfall and naturalized monthly flows for the Thames at Kingston; groundwater levels for the Chalk aquifer at Therfield Rectory; extracts from the BHS *Chronology*.

Figure 1 presents an example of data and information sources which helped to characterize an intense phase of the 1890–1909 drought. The long-term Central England Temperature (CET) series proved useful for confirming documented assertions of outstandingly high temperatures.

MAJOR DROUGHTS IN ENGLAND AND WALES

Data from all sources was combined to identify drought episodes in England and Wales from 1800 to the present day. Major droughts are listed in Table 2 and other notable events in Table 3; some hydrological judgement was required particularly for event magnitudes close to the notable/major threshold. Nonetheless, it is considered a strength of this study that the classification combines a range of data and information sources, rather than relying on a single index to characterize each drought. As Tables 2 and 3 demonstrate, drought is a recurring feature of the UK climate, with 10 major and more than 20 notable droughts identified over the 200 year period. Of particular note is the repeated clustering of successive dry years in the late nineteenth century, which in an extreme case (1890–1909) was maintained for almost two decades, despite some very wet interludes. Many of these events have been identified by other authors (Jones *et al*., 1997; Jones & Lister, 1998), using different selection criteria.

Table 2 Major droughts in England and Wales

Year	Duration	Comments
1995–97	Spring 95 – Summer 97	Major drought. Third lowest 18-month rainfall total for England and Wales (1800–2002). Long duration drought with intense episodes (e.g. affecting eastern Britain in hot summer of 1995). Initial surface water stress, then very depressed groundwater levels and much diminished lowland stream network.
1990–92	Spring 90 – Summer 92	Major drought. Widespread and protracted rainfall deficiencies – reflected in exceptionally low groundwater levels (in summer 1992, overall groundwater resources for England and Wales probably at their lowest for at least 90 years). Intense phase in the summer of 1990 in southern and eastern England. Exceptionally low winter flows in 1991/92.
1976	May 75 – Aug 76	Major drought. Lowest 16-month rainfall in E&W series (from 1766). Extreme in summer 1976. Benchmark drought across much of England and Wales – particularly the lowlands; lowest flows on record for the majority of British rivers. Severe impact on surface water and groundwater resources.
1959	Feb–Nov	Major drought. Intense 3 season drought – most severe in eastern, central and north eastern England. Significant spatial variation in intensity. Modest groundwater impact.
1933/34	Autumn 32 – Autumn 34	Major drought. Intense across southern Britain. Severe surface water impacts in 1933 followed by severe groundwater impacts in 1934, when southern England heavily stressed (less severe in the more northerly, less responsive, Chalk outcrops).
1921–22	Autumn 1920 – Early 1922	Major drought. Second lowest 6-month and third lowest 12-month rainfall totals for E&W. Very severe across much of England and Wales (including Anglia and South East; parts of Kent reported <50% rainfall for the year); episodic in North West England.
1890–1909	Long drought	Major drought. Long duration (with some very wet interludes). Initiated by an extremely dry autumn and winter (driest Sept–April period on record). Exceptional cluster of relatively dry winters. Major and sustained groundwater impact, with significant water supply problems. Most severe phases: 1893, 1899, 1902, 1905. Merits separate investigation.
1887/88	Late winter 87 – Summer 88	Major drought. High ranking rainfall deficiencies across a range of timeframes. Very widespread (across most of British Isles). Extremely dry 5-month sequence in 1887. Primarily a surface water drought – severe in western Britain (including North West).
1854–1860	Long drought	Major long duration drought. Sequence of dry winters in both the lowlands (seven in succession at Oxford) and northern England. Major and sustained groundwater impact.
1798–1808	Long drought	Major long duration drought. Three separate (non-overlapping) periods feature among the dozen lowest 18-month rainfall totals for England and Wales. Limited direct hydrological evidence, further investigation required.

Table 3 Other notable droughts in nineteenth and twentieth centuries.

1800–1900	1814–15; 1826–7; 1844–45; 1863–5; 1867–8; 1869–71; 1873–5; 1884–5
1900–2000	1911; 1913; 1914–15; 1919; 1929; 1937–38; 1941; 1943–44; 1947-49; 1955–56; 1962–65; 1972–73; 1988–89

TRENDS IN DROUGHT FREQUENCY AND MAGNITUDE

The study also investigated if there had been any discernible change in drought frequency and magnitude over the last 200 years. An Aridity Index (Marsh, 2004) was used to compare summer drought severity. As the equation below shows, this combines rainfall anomalies (homogenized England and Wales Series from 1767) and temperature anomalies (Central England Temperature Series) for the summer half-year, April to September, standardized by their respective standard deviations. The *Av.* represents the full record average of rainfall and temperature respectively:

Aridity Index = (*Rainfall – Av. Rainfall*)/*SD rainfall* + 0.5(*Temp – Av. Temp*)/*SD Temp*

As Fig. 2 demonstrates, the Aridity Index identifies the most familiar recent summer droughts (e.g. 1995, 1976 and 1959), but has less utility in identifying winter droughts or sustained periods of rainfall deficiency. Figure 2 shows a greater frequency of notably arid summer half-years in the recent past. This primarily reflects the exceptionally high summer temperatures over the last 30 years (Fig. 3), although the relatively low May–October rainfall over this period may also be influential (see Fig. 5).

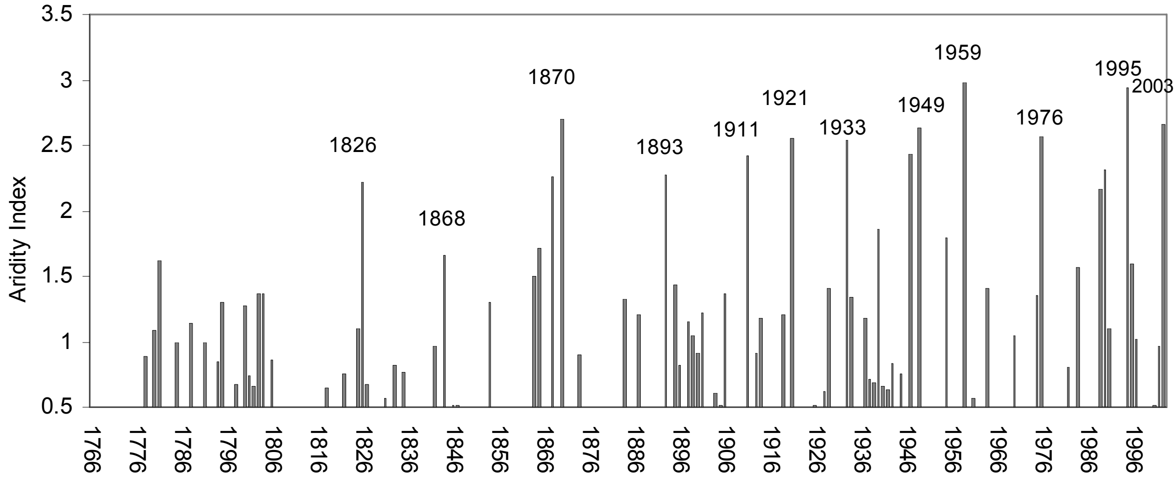


Fig. 2 Aridity Index for England and Wales (1776–2003).

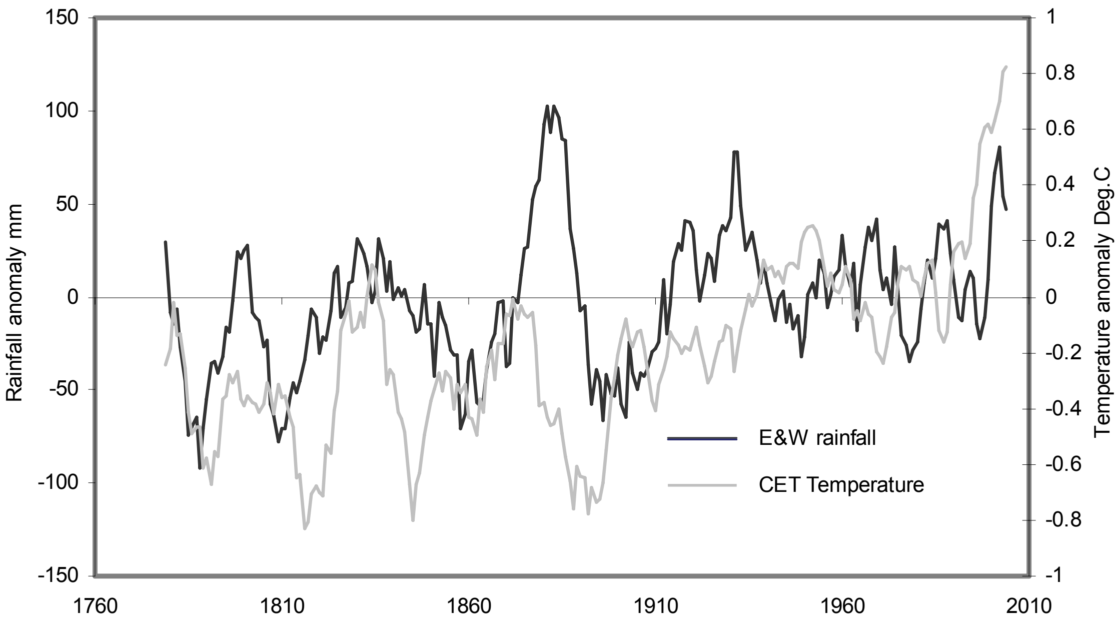


Fig. 3 Annual temperature (CET) and E &W rainfall anomalies (10-year moving average).

Figure 4 examines long-term 12-month rainfall deficiencies (based on any start month) for England and Wales. Exceptional rainfall events are distributed throughout the series. This is consistent with recent research (Hannaford & Marsh, 2006) which found no compelling trend in low flows in 45 natural benchmark catchments across the UK since 1963.

For water resources, the seasonal distribution of rainfall is particularly important, with the winter months critical for aquifer and reservoir recharge. Figure 5 compares long-term trends in summer (May–October) and winter (November–April) rainfall for the England and Wales rainfall series and five other rainfall series spatially distributed across England. These display substantial spatial and temporal variability in the seasonal distribution of rainfall. In high rainfall areas dominated by orographic influences, e.g. Central Lake District, the winter/summer partitioning of rainfall has remained relatively stable over time with winter rainfall consistently exceeding summer. The other four sites have low rainfall, more characteristic of lowland areas. Despite significant multi-year variability, these show a different seasonal distribution of rainfall in the nineteenth and twentieth centuries. In the nineteenth century, summer rainfall generally exceeded winter, while in the twentieth century the decline in summer rainfall has resulted in rainfall being roughly equal in the two seasons. Clusters of successive dry winters (and summers) are common throughout the record, often sustained for many years.

WATER RESOURCE IMPLICATIONS

The documentary and hydrometric evidence demonstrates that vulnerability to drought is not static, but changes with time. In the nineteenth century severe droughts often constituted a very real threat to lives and livelihoods; communities relied on a single or group of local sources for water and therefore had little scope for managing drought. Nowadays, we have complex and flexible multi-source supply systems and statutory drought plans. However, public and political perceptions of drought still tend to focus on intense summer droughts, such as 1976, 1995 and 2003. The 2003 drought, which extended across most of Europe, combined exceptional rainfall deficits with record-breaking high temperatures, with many severe and long-lasting impacts (UNEP, 2003). Unlike many European countries, the UK experienced no major restrictions on water use (Marsh, 2004), demonstrating the resilience of its water supply systems to short, intense droughts. However, the UK may be less resilient to a succession of dry winters, which, as the historical analysis and Fig. 6 show, have been relatively rare in the recent past (apart from 2005/06), but were substantially more common in the late nineteenth century. The 2005/06 drought in southern England is notable for the disproportionate contribution of the winter months to the overall rainfall deficiency.

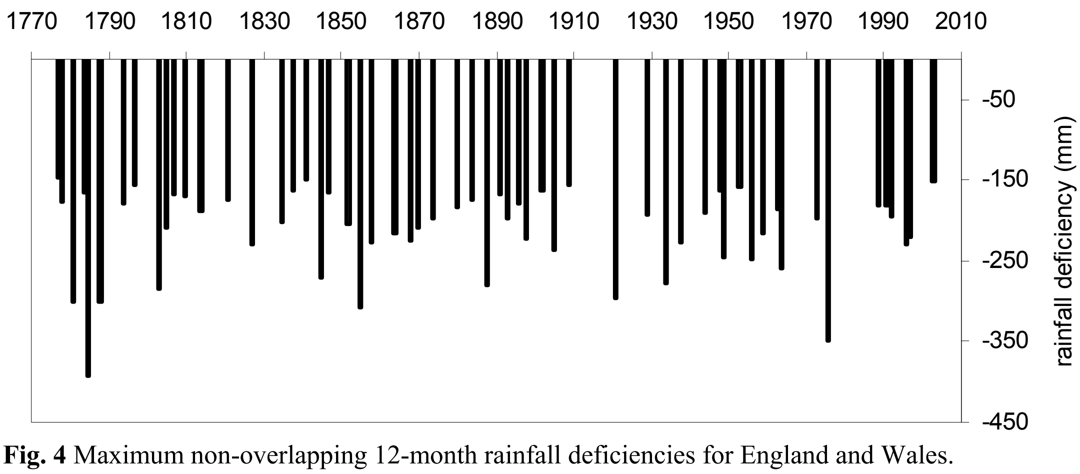


Fig. 4 Maximum non-overlapping 12-month rainfall deficiencies for England and Wales.

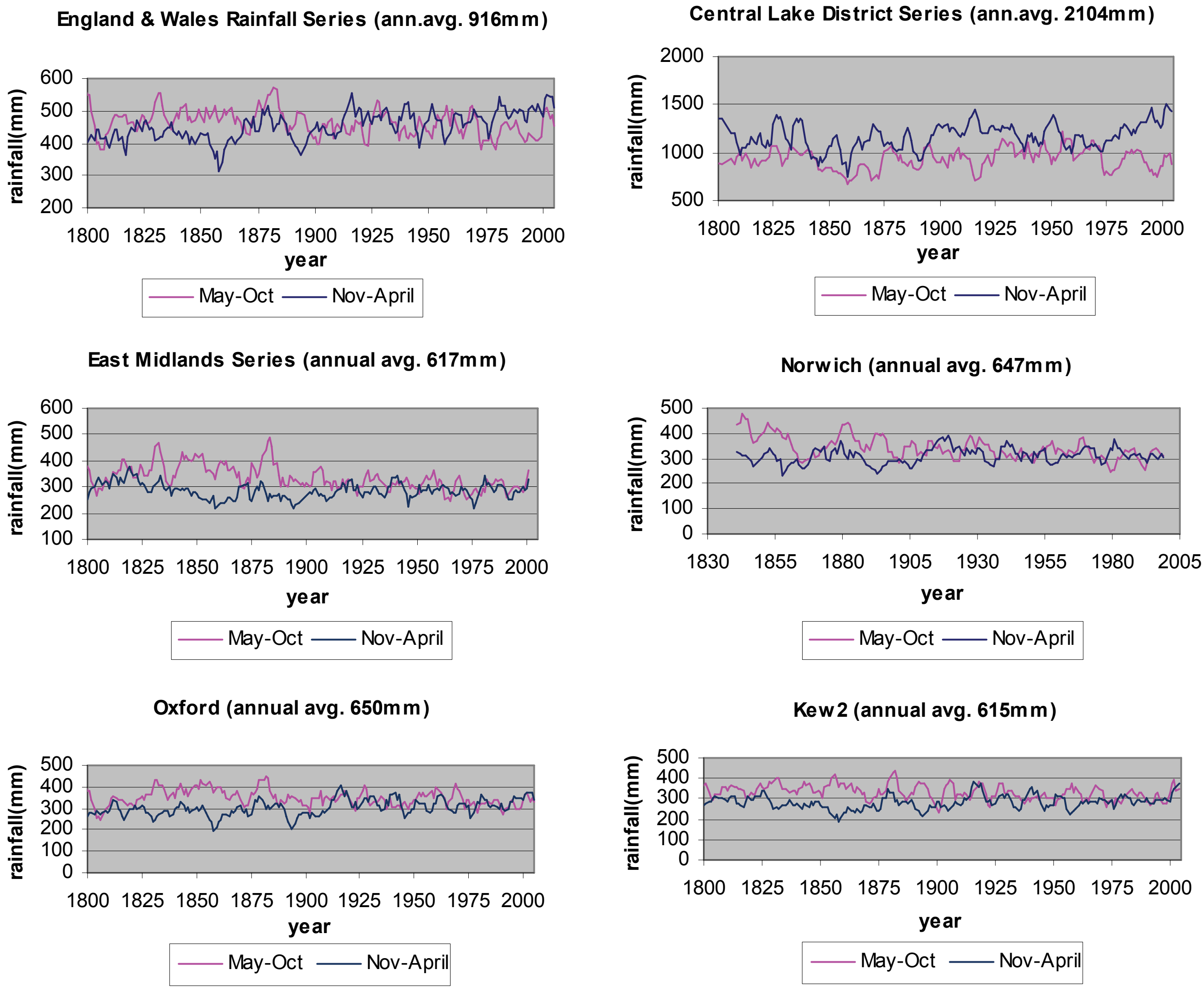


Fig. 5 Long-term summer and winter rainfall for the England and Wales rainfall series, and five raingauges distributed across England.

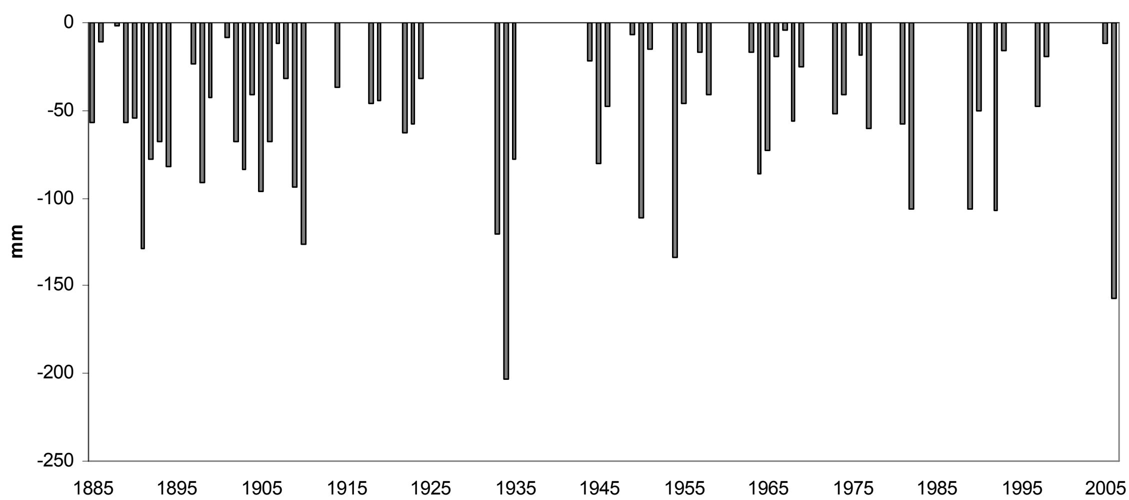


Fig. 6 Two-year November–January rainfall deficiencies in the Thames basin, 1885–2006.

Whilst most climate change scenarios indicate an increasing frequency of wet winters for the UK in a warmer world, the evidence presented here underlines the need for a fuller understanding of the mechanisms contributing to the substantial historical variability in rainfall patterns. A repeat of the protracted sequences of dry winters documented in Table 2 would represent a severe challenge to water management in the UK.

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