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2012: from drought to floods in England & Wales

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2012: from drought to floods in England & Wales

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This paper examines the exceptionally wet conditions which began in April 2012, abruptly terminating the prolonged 2010-12 drought across England & Wales (reviewed in Kendon *et al*. 2013) and culminating in exceptional runoff and aquifer recharge rates late in the year. The hydrological transformation during the late spring and summer of 2012 was without close modern parallel for the time of year.

Introduction

The inherent variability of the UK's climate achieved an extreme expression in 2012. By March, one of the most significant droughts for a century (Kendon *et al*. 2013) had resulted in exceptionally depressed spring river flows and groundwater levels with an expectation of more severe impacts on water resources, agriculture and the environment through the summer of 2012. In the event, the wettest April-July for England & Wales in almost 250 years decisively switched the focus of concern to a continuing, and extensive, flood risk.

Dramatic terminations of prolonged periods of drought have previously occurred in the historical record. For example, drought conditions in 1975-76, widely acknowledged as the most intense drought episode in the last 200 years at least (Rodda & Marsh 2011), were abruptly terminated during September and October, each of which saw more than twice the average rainfall over wide areas. However, a distinguishing characteristic of the 2010-12 drought was its termination during the April-July period. Normally, at this time of year, the majority of rainfall would be lost through evaporation, with river flows and aquifer recharge rates relatively depressed. By contrast, in 2012 near-saturated soils through late spring and summer contributed to a series of notable flood episodes affecting large parts of the UK.

Synoptic background and rainfall

For much of 2011 and early 2012, the Jet Stream guided rain-bearing low pressure systems to the north of the UK, resulting in sustained drought conditions across most of southern Britain. However, in early April 2012 there was a decisive change in weather patterns as the Jet Stream adopted a much more southerly track. Low pressure predominated over most of the UK, with a prevailing south-westerly airflow bringing heavy rainfall. This situation remained largely in place through much of the summer, with only brief interludes of settled weather in late May, late July, and across the south-east in August and early September.

A succession of low pressure systems brought sustained rainfall across the UK for most of April, at times accompanied by gales. Much of England, Wales and eastern Scotland received over twice the monthly average rainfall. It was the wettest April for the UK in a series beginning in 1910 and also the wettest in the near 250-year England & Wales Precipitation (EWP) series[1]. With an absence of spring warmth, it was the coldest April since 1989, and, unusually, colder than March (for the UK, March 2012 was the warmest since 1957).

The cool, unsettled conditions continued well into May, but rainfall totals were mostly near average for the month overall. June brought a return to exceptionally wet conditions with an almost complete absence of warm, settled spells – it was the coolest June since 1991. In a repeat of April, most of the UK again received well over twice the monthly average rainfall. With persistent heavy rain, and torrential downpours at times (e.g. on 28th when hourly rainfall rates of 20 to over 30mm were widely reported), it was the wettest June in the EWP series. In both April and June, a few locations approached four times the average rainfall, while for England & Wales, the April to June period was the wettest in the last 100 years by a margin equivalent to an additional month's rainfall.

Low pressure continued to predominate through the first two thirds of July. For the month overall, many parts of England, Wales and southern Scotland received more than twice the average rainfall. As a result, the April-July rainfall over England & Wales was almost twice the average (see Figure 1), and the highest in the EWP series from 1766 – easily exceeding the total for the previous seven months.

August was the driest month of the summer with rainfall totals across Lowland England[2] mostly near average. Some parts of the southeast were drier than average. Elsewhere, though, August was generally wetter than average, particularly across south-west England. For the UK overall, summer 2012 was the wettest since the extreme summer of 1912 (for more details of summer 1912, see Kendon & Prior 2011).

Weather patterns were very unsettled at times through the autumn and early winter, although there were also some quiescent spells. The first half of September was largely fine and dry. However, the latter half of the month brought significant flooding from a deep low pressure system associated with ex-hurricane 'Nadine', and a rapid succession of heavy rainfall events in late November resulted in one of the wettest weeks across England & Wales in the last 50 years; this was followed by the wettest December across England & Wales since 1934. As a result, 2012 was provisionally the second wettest year for the UK in the series from 1910 (just behind 2000) while for England, all areas where wetter than average (Figure 2) and 2012 was wettest in the series from 1910. In the EWP series from 1766, only 1872 and 1768 have been wetter.

The drier exception through much of 2012 – notably March-October – was the far northwest of Scotland, where significant drought stress in the Western Isles extended through the summer. Wildfires threatened historic buildings in Stornoway[3]; there were reports of springs drying up[4], with whisky production interrupted on Islay, Mull and Skye. In an often easterly airflow, the area was largely unaffected by many of the low pressure systems further south.

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[1] EWP series, after Alexander & Jones (2001). Throughout this article 'England & Wales' denotes England and Wales combined. For more information on data sources, see Kendon *et al.* (2013).

[2] The area of Lowland England is defined within the black solid line in Figure 1.

[3] Highland & Islands Fire & Rescue Service, Quarterly Performance Report. Accessed February 2013

[4] For example, at the end of June, the rain-gauge observer at Tornapress, Ross-shire reported their local spring running dry. "A good excuse to do no washing - fine until we all ran out of underwear!" (J. Baker, personal communication 10/07/2012)

April, June, April-July and April-December rainfall totals were the highest in each of the series shown in Table 1. Records were broken for many long-running stations; at Oxford, both April 2012 and June 2012 were the wettest in digitised records from 1853. At Durham, 1018mm of rain fell during 2012, the wettest year in records from 1880 by a margin of over 130mm.

Although 14 of the 24 months to March 2012 saw less than 70% of average rainfall (ten registering less than 55%), six of the following nine months from April-December 2012 saw over 140%, with three months greater than 200% (Figure 3). As much rain fell across Lowland England in the nine months spanning April-December 2012 as during the previous 19 months (September 2010 to March 2012), demonstrating the remarkable hydrological transformation through 2012. Interestingly, for the drought and subsequent transformation combined (April 2010 to December 2012), the overall rainfall accumulation across Lowland England was near average.

Evaporation and soil moisture[5]

Seasonally extreme soil moisture conditions in 2011 and 2012 contributed to both the intensity of the drought and to the extent of the flooding through the summer half-year of 2012. Evaporation rates through the winter half-year of 2011/12 remained within the normal range but the driest October-March for England & Wales since 1975/76 resulted in late March soils at their driest conditions on record by a considerable margin[6].

The outstanding April rainfall rapidly eliminated the record early spring soil moisture deficits (SMDs). Thereafter, whilst short-term fluctuations in soil moisture were common, there was no sustained development of deficiencies (i.e. drying of soils) that normally characterises the summer months (see Figure 4).

Average SMDs for the summer half-year (April-September) in 2012 registered a new period-of-record minimum in the series from 1961 and, remarkably, were lower than the average for the preceding winter half-year (2011-12), the only time this has occurred in a series from 1961. The pattern of SMDs in 2012 represents an outstanding departure from the normal annual cycle.

Runoff

Outflows from Great Britain in March 2012 were the lowest on record (in a series from 1961; CEH Wallingford 2013) and flows in many rivers during the final week fell below those recorded at the same time in 1976. More notably, overall runoff deficiencies (built up over 23 months to March 2012) for Lowland England – where both droughts achieved their greatest intensity – exceeded those built up through the shorter 16-month 1975-76 drought. Flows continued to decline into early April when, for the time of year, the contraction in the stream network was extreme (Kendon *et al*. 2013).

Thereafter, the seasonally outstanding rainfall from April to July served to effectively terminate the drought but the rate and magnitude of the runoff recovery was substantially influenced by differing catchment characteristics. Flows increased rapidly in most impermeable catchments and, by the

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[5] For an introductory summary of soil moisture deficits, see Kendon *et al*. 2013 (Evaporation and Soil Moisture, first paragraph)

[6] Based on the MORECS series (for a grass cover), 1961-2012 (Hough & Jones 1997). MORECS soil moisture deficit data refer to end-of-month conditions.

final week of April, flood alerts were widespread – affecting rivers from Cornwall to north-east Scotland. For England & Wales as a whole, late-April outflows exceeded the previous maximum in a series from 1961 (see Figure 5). After a relative respite in May, exceptional runoff rates continued well into the summer, with permeable catchments also showing significant (if lagged) response. The seasonally remarkable runoff rates helped replenish drought-affected wetlands and extend the drainage network into the previously dry headwater reaches of many rivers.

Whilst there were many fluvial flood events during the summer half-year, widely distributed across the country, few events could be described as extreme when considered individually. The main exceptions to this were the floods in Cumbria in June (208mm rainfall was recorded at Honister Pass on 22nd June) and in Morpeth (Northumberland) in September, and, most severe, the event on the River Rheidol (near Aberystwyth) in June, when two-day rainfall totals of 186mm caused the evacuation of more than 1,000 people from their homes. The Environment Agency reported that over 4,000 properties in England and Wales had suffered fluvial or flash flooding by the end of August, a figure that would have been substantially higher in the absence of flood protection measures. The geographical spread of catchments subject to floodplain inundations was remarkable. Since 1960, only in 2007 were comparable summer outflows recorded – in June and July (Marsh & Hannaford 2008) – but in 2012, with the exception of August, seasonally outstanding flows were registered in each month of the summer half-year (April-September). Summer half-year outflows for England & Wales were more than twice the 1961-2011 average, and exceeded the previous maximum (2008) by over 30%. As notably, summer half-year outflows exceeded those for the previous winter half-year, for the first time on record.

Runoff rates climbed once again in November and December, and flooding was both extensive and sustained. Outflows for the last fortnight of 2012 from England & Wales were among the highest for any such two-week sequence in the last 50 years (the highest being late-October/early-November 2000).

Reservoir stocks

Whilst the seasonally outstanding river flows in the summer of 2012 constituted a continuing flood risk, the impact of the exceptional summer runoff on water resources was very beneficial.

Following the largest March decline in reservoir stocks on record for the UK, many reservoirs, particularly in Lowland England, had depressed stocks in the early spring. Hosepipe bans affecting 20 million consumers were introduced in anticipation of a continuing decline in stocks through the summer of 2012.

However, the remarkable April runoff rapidly restored stocks in many northern and western reservoirs to within the normal spring range. In notable contrast to the normal seasonal pattern, June saw a ~5% rise in overall reservoirs stocks for England & Wales, unprecedented in the series from 1990, and most reservoirs stocks were well above the seasonal average by mid-summer. In East Anglia, Rutland reservoir recorded its largest two-month recovery in stocks in a series from 1988, and established new monthly minima and monthly maxima within a three-month period (end of March to end of June; Figure 6). Across Lowland England as a whole, reservoirs registered the largest increase in stocks through the summer half-year on record and generally all index reservoirs with the exception of Bewl (East Sussex) were within 10% of capacity at the end of August.

Remarkably, the average summer (June-August) reservoir stocks for England & Wales in 2012 surpassed the average winter stocks (December-February) for all previous years back to 1990, and by the end of 2012, overall end-of-year reservoir stocks for England & Wales were at their highest on record.

Groundwater

Groundwater is the principal water supply source across much of Lowland England, where the 2010-12 drought achieved its greatest intensity. By March 2012, with rainfall deficiencies through successive winters having left groundwater levels very depressed and an increasing number of private wells beginning to fail, the water resources outlook was fragile. With seasonal declines commencing from an exceptionally low starting point, there was very little prospect of any early recovery in groundwater resources.

However, as with SMDs and runoff, groundwater levels exhibited outstanding departures from the normal seasonal cycle throughout 2012. Facilitated by the remarkably wet soils, aquifer recharge, normally meagre through the late spring and summer, was both substantial and sustained from late April. Aquifer storage properties, local rainfall patterns and the depth to the depressed water tables considerably influenced the responses of groundwater levels in individual wells and boreholes. The faster responding aquifer units showed almost immediate groundwater level increases in April; levels in the Jurassic Limestone of the Cotswolds and in some parts of the southern Chalk (e.g. at Chilgrove in West Sussex) rose rapidly, and a remarkable increase of four metres in a single day (April 29th/30th) was observed in the well-fissured Carboniferous Limestone of South Wales. However, elsewhere the primary benefit of the April rainfall was to eradicate SMDs and allow groundwater replenishment in subsequent months.

As the wet summer continued, the very unusual seasonal recovery in groundwater resources gathered momentum. All of the Jurassic and Magnesian Limestone aquifers in eastern and south-central areas of England showed significant increases in groundwater levels during June; the level at Alstonfield in Derbyshire rose by 14m to exceed its previous June maximum by a considerable margin. Levels in the Chalk of the southern counties also responded rapidly, with new monthly maxima approached or established in the South Downs, Dorset and Wiltshire. At Tilshead (on the Salisbury Plain), where groundwater levels entering 2012 were comparable with the minima registered in 1976, mean levels in July, August and September all equalled or exceeded previous monthly maxima (Figure 7). Instances of groundwater flooding – a very rare summer occurrence – began to be reported (e.g. at Winterbourne Abbas in Dorset) as early as July. By contrast, late-summer levels remained notably depressed in some Chalk outcrops (e.g. the Chilterns) and the Permo-Triassic sandstones of the Midlands – where water table response to surface infiltration can take six months or more.

Abundant recharge over the last two months of 2012 ensured that groundwater levels were close to, or above, previous end-of-year maxima across large parts of the major aquifer outcrop areas. With significant amounts of water still percolating through the unsaturated zone and the prospect of further increases in levels, the outlook for winter 2012/13 was of a continuing increased risk of groundwater flooding, particularly in the Chalk.

Impacts of the transformation

Following an extended period of dry soils and difficult growing conditions, the eradication of SMDs through April was initially welcomed by the agricultural sector. However, before long there was a new set of problems with which to contend. Waterlogging inhibited access to land, reduced yields and caused some crops to rot. Concerns in mid-Wales arose regarding potential contamination of agricultural land with harmful heavy metal pollutants eroded from the spoil heaps of abandoned mines. Floodwaters often marooned livestock and affected fodder production. The National Farmers Union estimated the cost to rural Britain from the exceptionally wet weather in 2012 had run to £1.3bn[7].

There were serious consequences for infrastructure. On the roads, debris and surface water closed some main roads and travellers were marooned in cars. The rail network fared little better, with tracks subject to landslides of unstable waterlogged ground; in late June, both the West Coast and East Coast mainlines to Scotland were blocked by landslips. The Tyne and Wear Metro was completely shut down due to flooded tunnels and collapsed walls on 28th June, and Birmingham Airport diverted arriving aeroplanes in late June. Significant landslides affected the south-west coast, including the Jurassic Coast in Dorset, and at Whitby (North Yorkshire).

Flooding was widespread and sustained, owing to the persistence of rain-bearing frontal systems over a number of months – particularly in April, June and early July, late November and late December. As the summer progressed, saturated soils increased the risk of surface water flooding. Areas of West Yorkshire were subject to flash flooding from the River Calder three times in two weeks across June and July. There were large-scale evacuations in Wales, Yorkshire, and eastern Scotland at times throughout the year, with caravan parks particularly badly affected by rising water levels.

Floodplain inundations and rising water levels had mostly adverse ecological effects. Although initially beneficial, the rising water levels in wetlands and nature reserves destroyed nests of ground-nesting birds (e.g. in the Ouse Washes). The recession of floodwaters stranded fish on floodplains, and part of the annual swan census in Sudbury-on-Thames, Surrey was cancelled, perhaps for the first time in its 900-year history.

Leisure activities were disrupted throughout the summer months; festival-goers on the Isle of Wight were stranded in cars overnight and numerous events were postponed or cancelled. The Badminton Horse Trials were cancelled for only the second time in their history (the first being 2001 due to foot-and-mouth disease), and racing car enthusiasts were encouraged not to attend Formula 1 practice sessions at a waterlogged Silverstone. The Olympic torch relay continued on in spite of bad weather, though the Olympics and Paralympics themselves coincided with a fair amount of fine weather.

Many of the flood incidents in 2012 were localised in nature and caused by torrential downpours (rainfall rates often exceeded 20mm per hour) overwhelming drainage systems, rather than large-scale fluvial flooding. But despite record rainfall, there were no flood incidents of the scale of those experienced in the Midlands and Yorkshire in the summer of 2007 or in Cumbria in November 2009. In total for 2012, the 8,000 properties[8] flooded represent a surprisingly low number given the record volume of runoff, a testament to the network of flood defences. The exceptionally dry early-April

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[7] National Farmers Union, Press Release, 2013

[8] According to the Environment Agency (http://www.bbc.co.uk/news/science-environment-20898729)

soils and timing of dry spells in late May and late July were also important moderating factors. By contrast, in 2007, regionally focussed and sustained high intensity rainfall during three *consecutive* months of very wet weather resulted in over 55,000 homes and businesses being flooded (Environment Agency 2007). The flooding in 2007 was less spatially extensive, but much more damaging overall than in 2012.

The wet late spring and early summer rainfall unexpectedly, and rapidly, improved the water resource situation. Drought conditions eased in the West Midlands and south-west England in mid-May; Anglian, Thames and Southern Water lifted hosepipe bans in mid-June and the remaining water companies lifted their restrictions in July.

Discussion and historical perspective

The UK has a rich legacy of hydrometeorological datasets, allowing the 2010-12 drought and subsequent hydrological transformation to be viewed in a very long historical context.

2012 witnessed the second driest January-March for England & Wales since 1953 and thence the wettest nine-month sequence (for *any* start month) in the ~250-year EWP series. Such dramatic partitioning of the annual rainfall total is exceptionally rare. Table 2 provides a comparison with other four-month rainfall totals following sustained droughts in Lowland England in the last 100 years (presented in Kendon *et al.* 2013). For the period April-July 2012, 202mm of the 326mm deficit (i.e. more than 60%) which accumulated over the previous 24-month period was recovered – almost twice the average for this four-month period. By comparison, only around 30% of the extreme rainfall deficit built up from May 1975 to August 1976 was recovered in the four months from September to December 1976 (see Table 2).

The exceptional rarity of 2012 in a hydrological context is reinforced by actual runoff data. In a series from 1961, the May-July[9] runoff for England & Wales has never reached two-thirds of that for the preceding January-March; in 2012, it exceeded 150%. A more extended historical perspective is provided by Figure 8 which plots the mean May-July flows for the Thames at Kingston as a proportion of the mean flow for January-March**.** 2012 is clearly outstanding in a series from 1883; the only other occasions when the May-July runoff has exceeded that for the preceding January-March are 1932 and 1903. In summer 1903, flooding was significantly more extensive than in 2012 but the recovery from earlier drought conditions was well established before the spring.

Examples of major floods and drought conditions occurring in the same year are not particularly rare. In 1947, the impact on society of the March flooding – the most extensive across England & Wales in the 20th century – and the ensuing drought conditions were immeasurably greater than those of 2012. There are also a number of examples of rapid recoveries in river flows following a notable drought in the last 100 years (e.g. 1992, 1989, 1976, 1963, 1959, 1929 and 1922). Nevertheless, whilst some of these recoveries were equally dramatic, 2012 was notable for the prolonged nature of wet conditions, and, crucially, none of the other recoveries occurred through the summer half-year.

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[9] Whilst the hydrological transformation covered April - July 2012, the lagged response of rivers to significant rainfall in April necessitates runoff response to be evaluated over the May - July 2012 timeframe.

The timing and magnitude of the transformation in groundwater resources through 2012 was also remarkable. The Chilgrove House well in the Chalk of the South Downs has one of the longest groundwater level records in the world, beginning in 1836. By the end of 2011, groundwater levels had fallen to the natural base level[10] but the recovery was such that mean levels in June and July 2012 were the highest on record; and levels over the May to August period have been closely approached only in 1879. By December, groundwater levels were approaching the historical maximum[11] for the early winter with a significant risk of groundwater flooding continuing into early 2013.

Why did the hydrological transformation occur?

The abrupt change in weather patterns and Jet Stream position across the UK in early April, and the persistence of extremely wet conditions through large portions of the subsequent nine months, could simply reflect natural variability of the UK climate. A multitude of influences from both the neighbouring North Atlantic and also from tropical weather patterns, as well as climate events such as El-Nino Southern Oscillation, may affect northern Europe. The possible influences from 20th century global warming, a warming Arctic, and associated loss of sea ice, are also active areas of research.

Disentangling the effect of these various often competing influences is extremely complicated. However, Sutton and Dong (2012) demonstrate that a general shift to a pattern of wet summers in northern Europe and hot dry summers in southern Europe since the 1990s has coincided with a marked warming of the North Atlantic related to the Atlantic Multidecadal Oscillation (AMO). (A similar state was last seen in the 1950s, a period which also contained a number of relatively wet summers for the UK, e.g. summers 1956 to 1958). Warm sea surface temperatures in the North Atlantic in spring have a tendency to drive lower pressure and heavy rainfall across the UK and Europe (Knight *et al*. 2006).

2012 has served to underline the continuing vulnerability of the UK to extreme weather patterns, and the need to develop effective strategies to mitigate their increasing range of impacts. The conditions experienced in 2011-12 are at the extreme range of historical variability, but in a warming world, the past may not be the best guide to the future. Nonetheless, notwithstanding the compelling rise in temperatures, there are, as yet, few compelling long-term trends in rainfall, river flows and groundwater levels (Jenkins *et al*. 2009; Hannaford & Marsh 2008; Marsh & Harvey 2012; Hannaford & Buys 2012). Clearly, it is imperative to maintain hydrometeorological monitoring networks with the capability to identify and quantify long-term changes in the variables that conspired to make 2012 such a remarkable year.

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[10] Natural base level is the level at which natural drainage, via springs and seepages, ceases. Thus no further decline in levels would be expected.

[11] Comparisons between historical and contemporary groundwater level data must be carefully considered because the frequency with which groundwater levels are measured has increased in the recent past.

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Information on the climate of the UK, including monthly, seasonal and annual summaries and statistics, is available at: http://www.metoffice.gov.uk/weather/uk/climate.html

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Table 1 Areal rainfall statistics expressed as percentage of 1971-2000 average and ranking in the series -- for the UK, England & Wales (E&W), Lowland England (ELOW), and EWP series (EWP). (New records bold, higher years bracketed). Based on provisional data from September-December 2012.

Series	April	June	July	Apr-Jul	Jun-Aug	Apr-Dec	2012
UK (1910-)	**184%** **1st**	**205%** **1st**	171% >10th	**166%** **1st**	167% 2nd (1912)	**137%** **1st**	119% 2nd (2000)
E&W (1910-)	**232%** **1st**	**239%** **1st**	202% 9th	**194%** **1st**	190% 2nd (1912)	**157%** **1st**	**132%** **1st**
ELOW (1910-)	**257%** **1st**	**221%** **1st**	225% 4th	**199%** **1st**	182% 2nd (1912)	**158%** **1st**	**134%** **1st**
EWP (1766-)	**242%** **1st**	**237%** **1st**	210% >10th	**197%** **1st**	190% 4th (1912, 1879, 1829)	**161%** **1st**	134% 3rd (1872, 1768)

Table 2 Areal rainfall figures for droughts across Lowland England since 1910, ranked by rainfall deficit, together with surplus rainfall over the subsequent four months.

End month	Duration (months)	Deficit (mm)	Surplus (mm) next 4 months
04/1997	25	422	79
12/1921	17	379	56
02/1992	24	370	-7
08/1976	16	356	109
03/2012	24	326	202
11/1934	20	315	21
09/1949	26	312	8
06/1944	17	281	57
05/1974	22	277	92
11/1989	16	237	77
02/1965	15	229	3
04/2006	18	227	27

NB: In this analysis, drought durations vary from 15 to 26 months. However, the ‘surplus’ rainfall is always assessed over the subsequent ‘fixed’ four-month period (allowing level comparison with the four-months April to July 2012). The seasonal timing and differing duration of drought recoveries make like-for-like assessment problematic, and the termination point of many droughts may be less clear-cut than that of 2010-2012.

Figures

Figure 1. Rainfall anomalies for the period April 2012 to July 2012, also delineating Lowland England (solid black line). Data source: UK Met Office.

Figure 2. Rainfall anomalies for the year 2012. Data source: UK Met Office.

Figure 3. Monthly rainfall anomalies, relative to 1971-2000 average, for Lowland England for March 2010 to December 2012. Data source: Met Office.

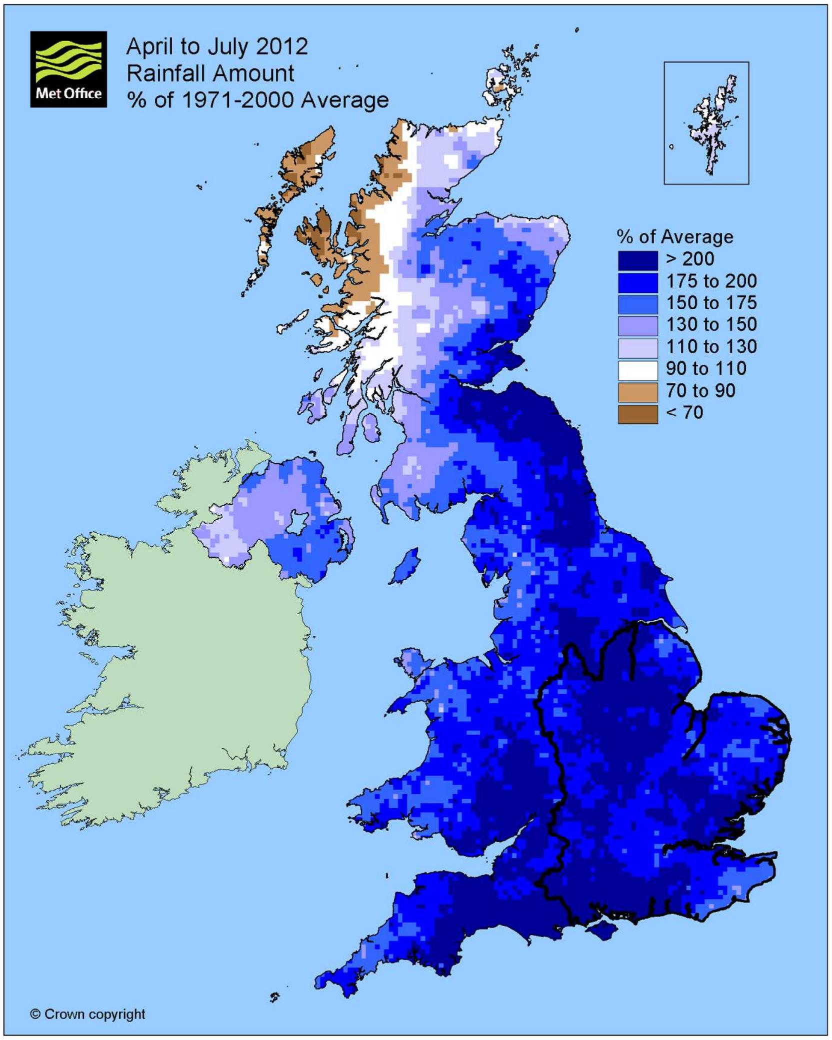
Figure 4. End-of-month soil moisture deficits (SMDs) averaged across Lowland England (black trace), 2011-12. The pink and blue envelopes represent the highest (dry) and lowest (wet) monthly SMDs, respectively, for the 1961-2010 period, whilst the grey trace is the long-term average. Data source: MORECS (Hough & Jones 1997).

Figure 5. Estimated daily outflows (m^3 s^{-1}) from England & Wales (black trace), 2012. The blue and pink envelopes represent the highest and lowest daily outflows for the 1961-2011 period, whilst the grey trace is the long-term average. Data sources: Environment Agency, Scottish Environment Protection Agency.

Figure 6. End-of-month stocks in Rutland reservoir (% of capacity), 2011-Aug 2012 (black trace). The blue and pink envelopes represent the highest and lowest stocks recorded (1988-2010), whilst the grey trace is the long-term average. Data source: Anglian Water.

Figure 7. Monthly mean groundwater levels (m) at Tilshead, Salisbury Plain, 2011-12 (black trace). The blue and pink envelopes represent the highest and lowest monthly average levels for the 1961-2010 period, whilst the grey trace is the long-term average. Data source: Environment Agency.

Figure 8. Ratio of May-July flows to January-March flows for the Thames at Kingston (naturalised data shown, removing the impact of artificial influences). Data source: Environment Agency.


Met Office
April to July 2012
Rainfall Amount
% of 1971-2000 Average
% of Average
> 200
175 to 200
150 to 175
130 to 150
110 to 130
90 to 110
70 to 90
< 70
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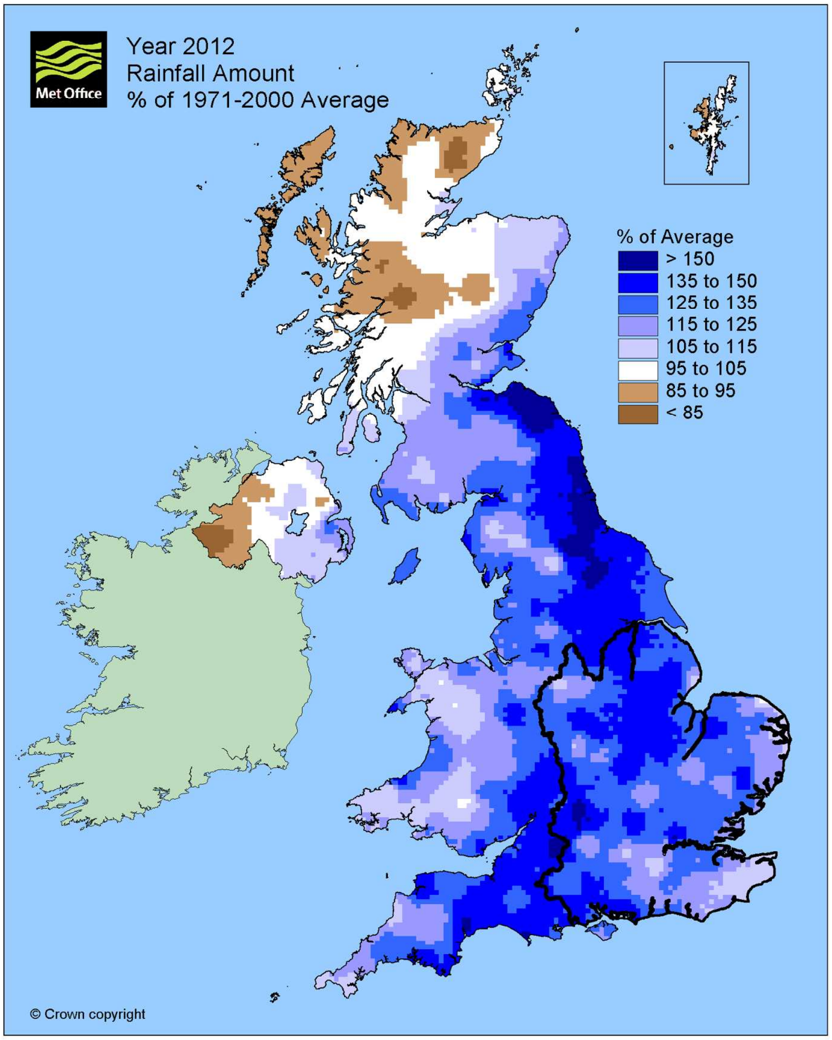
Met Office
Year 2012
Rainfall Amount
% of 1971-2000 Average
% of Average
> 150
135 to 150
125 to 135
115 to 125
105 to 115
95 to 105
85 to 95
< 85
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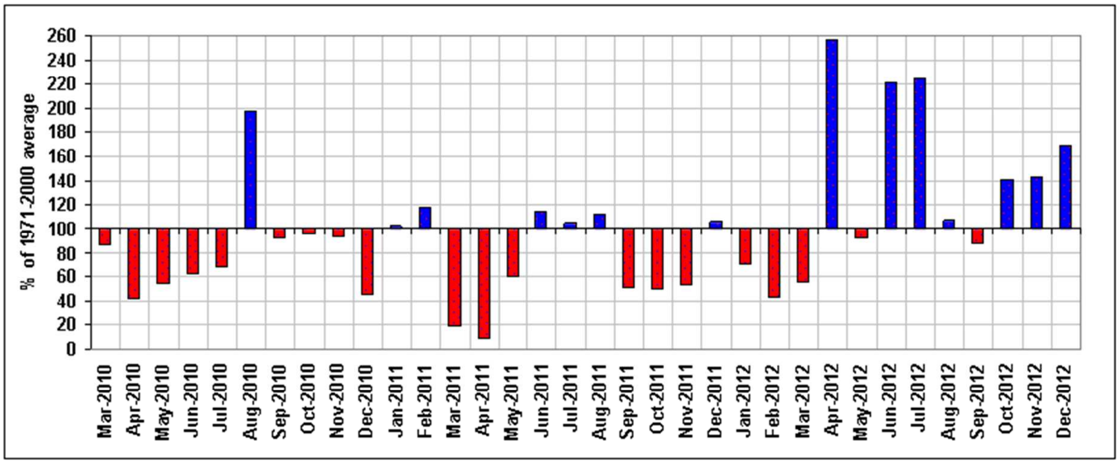
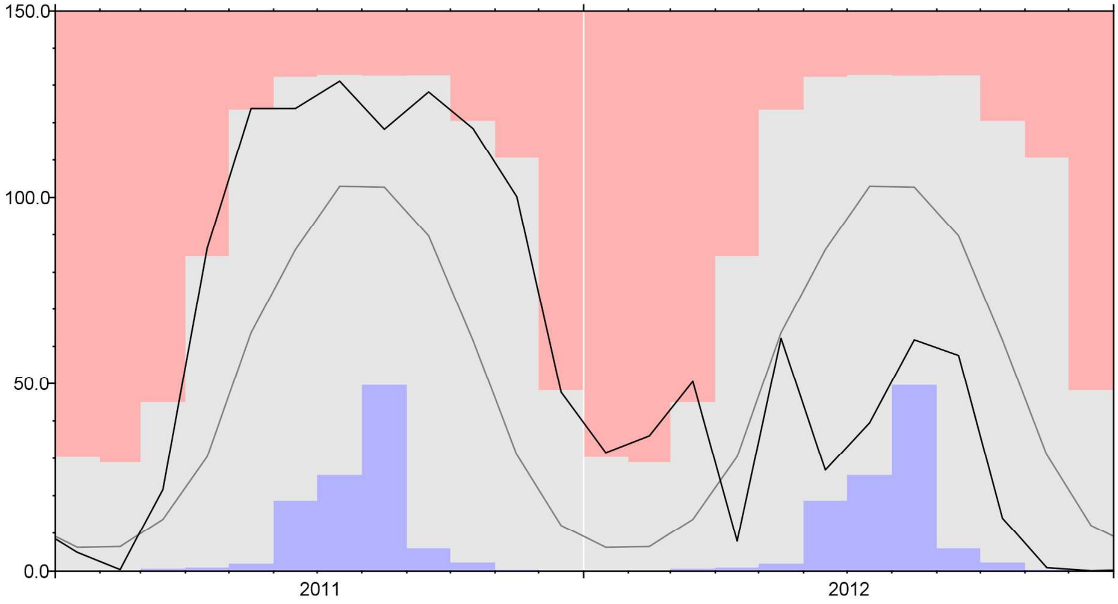
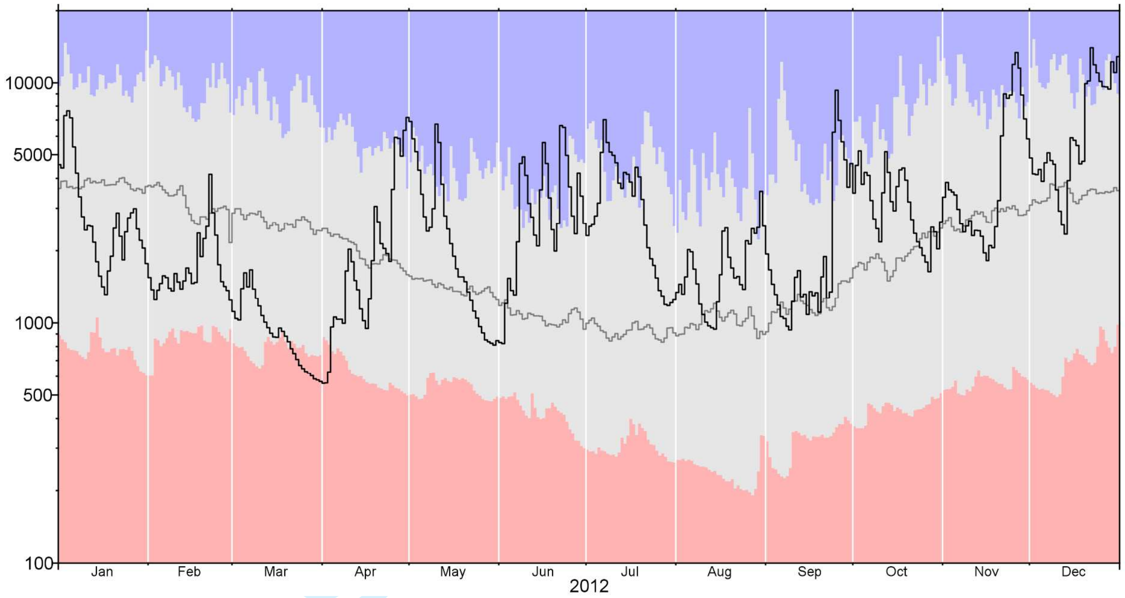
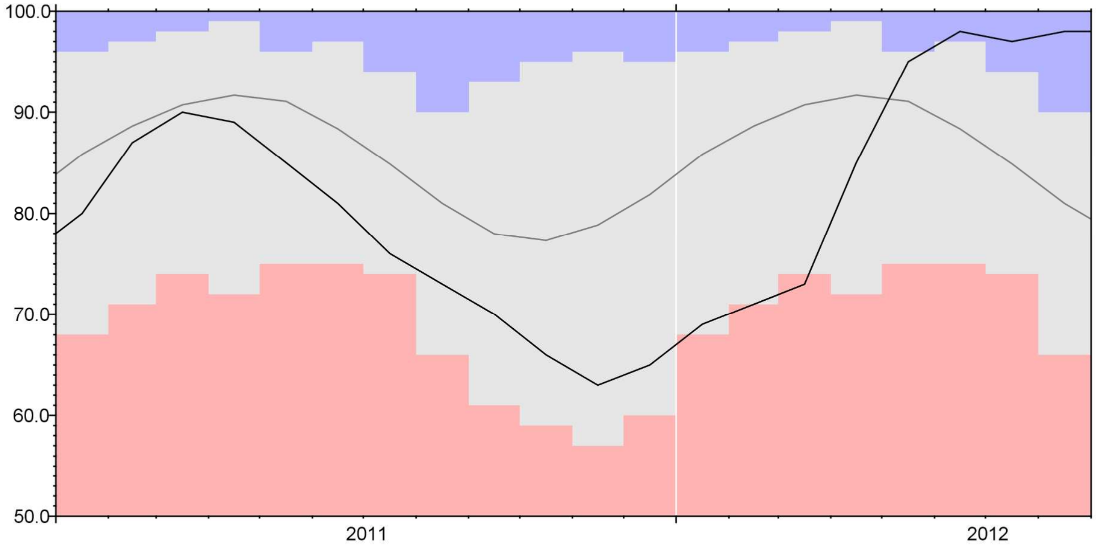

% of 1971-2000 average
260
240
220
200
180
160
140
120
100
80
60
40
20
0
Mar-2010
Apr-2010
May-2010
Jun-2010
Jul-2010
Aug-2010
Sep-2010
Oct-2010
Nov-2010
Dec-2010
Jan-2011
Feb-2011
Mar-2011
Apr-2011
May-2011
Jun-2011
Jul-2011
Aug-2011
Sep-2011
Oct-2011
Nov-2011
Dec-2011
Jan-2012
Feb-2012
Mar-2012
Apr-2012
May-2012
Jun-2012
Jul-2012
Aug-2012
Sep-2012
Oct-2012
Nov-2012
Dec-2012


150.0
100.0
50.0
0.0
2011
2012


10000
5000
1000
500
100
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2012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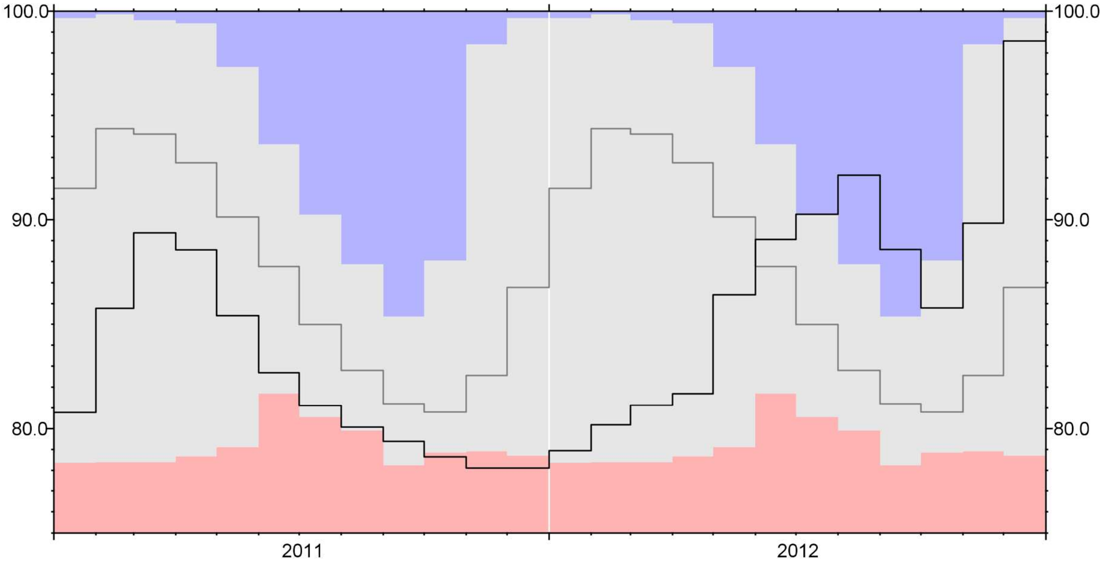
90.0
80.0
70.0
60.0
50.0
2011
2012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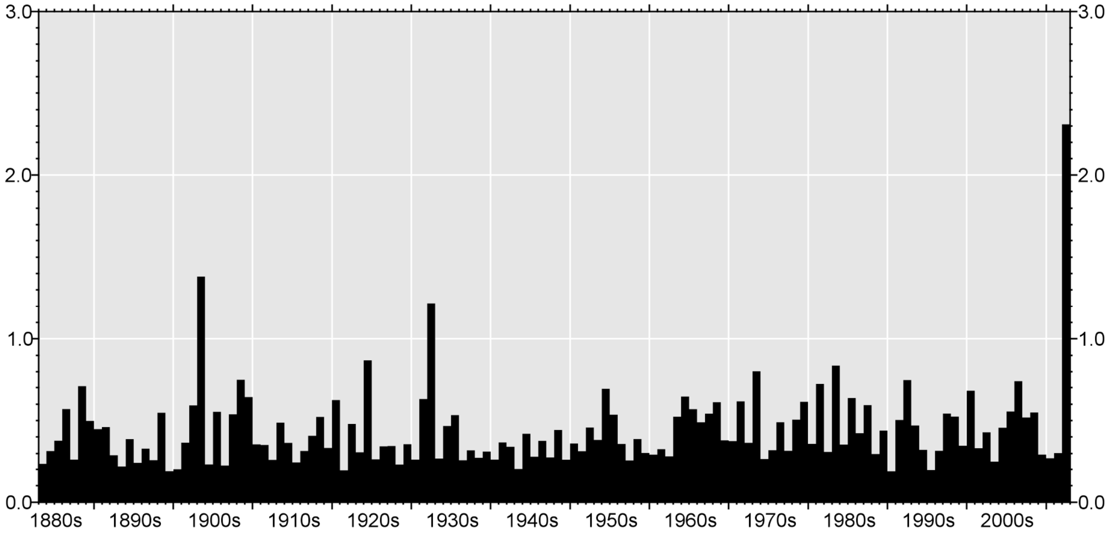
90.0
80.0
100.0
90.0
80.0
2011
2012


3.0
2.0
1.0
0.0
3.0
2.0
1.0
0.0
1880s
1890s
1900s
1910s
1920s
1930s
1940s
1950s
1960s
1970s
1980s
1990s
2000s