LOCAL CLIMATE AND CLIMATE CHANGE IN LOWLAND WEST SOMERSET

SIMON RATSEY
Formerly of the Leonard Wills Field Centre, Nettlecombe Court, Somerset

This paper compares the climate at Nettlecombe Court with two other stations further inland in West Somerset. The three recording sites and the data used in this study are carefully described. Coverage of temperature includes mean air temperature, monthly and seasonal variations, spells of hot and cold weather and extremes of temperature. A similar coverage is given for rainfall including extreme daily rainfall totals and the occurrence of wet spells and droughts. The study ends with some observations on climate change in the last half century.

INTRODUCTION

School geography textbooks have for generations been inclined to describe the climate of south-west England as "mild and damp", with the added information that in the upland areas such as Dartmoor and Exmoor it is "cool, wet and windy". Even in the detailed and arguably definitive work *Regional Climates of the British Isles* (Wheeler and Mayes, 1997), the section on the South-West begins with the stereotypical contrast between coast and moor. This is in part because the data sources used in the book are climatological stations reporting to the UK Meteorological Office (UKMO), the majority of them being in coastal locations. (Although it uses the climatological reference period 1961 – 1990, that book sets out a very helpful context for detailed studies of this nature.) Some of the coastal recording sites were established in the past as Health Resort stations to gather information that might help in their promotion, a few having a very long data series. The nuances of coastal climate in the region are further highlighted in detailed studies such as that for Slapton Ley (Burt and Horton, 2001). Inland recording stations featured in the book are relatively few in number and predominantly in the upland areas, the significant gaps in the network for mid-Devon and Somerset being freely acknowledged.

FIGURE 1. Map showing the locations of the recording sites featured in this paper.

The reality is that there is great deal of variation in local climate in the lower-lying parts of the region, largely the result of topography and exposure to, or protection from, maritime influences. Local inhabitants are very conscious of this, knowing that weather conditions at any given time can often vary greatly between locations only a few miles

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apart. The Somerset Levels, in the central part of that county, are recognised in the afore-mentioned book as having a distinctive and, for the region, unusual climate. However, the specific characteristics of the weather and climate experienced by non-coastal lowland areas in the western half of Somerset, an area in excess of 250 square kilometres, are scarcely acknowledged. For this area, depicted by the map in Figure 1, a considerable body of climate data has now been collected, over a period of almost sixty years.

The present author spent his youth on Cobhay Farm, 7 km north-west of Wellington and near the western end of the district known as the Vale of Taunton Deane. He began the daily recording of maximum and minimum temperatures in 1960 and of daily rainfall in 1962 and grew up with an awareness of the significant variations in local climate from place to place. In common with many amateur weather observers, it would seem, his inspiration was *Climate and the British Scene* (Manley, 1952)[1]. While the equipment used and its exposure did not conform to UKMO standards, the records have proved very valuable for research purposes. With a few short interruptions, the daily observations at the farm were maintained by the author's father until late in the year 2000.

In 1967, a Field Studies Council (FSC) centre was established at Nettlecombe Court on the northern side of the Brendon Hills, 5 km from the Bristol Channel coast. It began serving as a climatological station for the UK Meteorological Office (UKMO) in the summer of 1968, the weather being recorded daily at 0900 GMT. All equipment involved conformed to the official standards. Summaries of those records appeared in the UKMO *Monthly Weather Report* until that ceased publication in 1993. The author, a staff member at Nettlecombe Court from September 1968 to August 1972, produced a paper analysing and interpreting the first four years' data from the weather station there (Ratsey, 1973). That paper remains a useful introduction to the topic in hand.

Since early 1987 the author has lived on the southern side of Wellington, about 20 km SSE of Nettlecombe. Daily records of temperature and rainfall have been kept continuously, with a diary of weather notes in more recent years. A home-made screen houses a variety of thermometers, which were checked for accuracy against the Nettlecombe thermometers by being placed in the Stevenson Screen at that site. A mercury-filled maximum-minimum thermometer and a very basic electronic sensor, both in use now for almost twenty years, were confirmed as providing the most accurate measurements. The internet has in recent years enabled the cross-referencing with other data sets, which suggest that the Wellington records are valid and certainly accurate enough for the purposes of this present study. The 5-inch funnel copper Symons rain gauge conforms to UKMO standards and has been in use for sixteen years. Prior to that, a home-made 5-inch funnel rain gauge and measuring cylinder were in use at the site. Comparisons of readings from both gauges during an overlap period of several weeks indicated that the earlier measurements were surprisingly accurate.

This study will focus mainly upon air temperatures and rainfall in this part of West Somerset, those being the climatic elements that have been recorded at all three sites, permitting meaningful comparisons to be made.

THE THREE RECORDING SITES

The weather station at Nettlecombe Court is 96 m above mean sea level (ASL), the author's own in Wellington at 90m, while the one at Cobhay Farm was at 120 m. Nettlecombe is at the bottom of a fairly steep-sided valley at the north-eastern corner of the Brendon Hills (summits >300 m ASL), the weather station being on a level grassy area adjacent to the main front lawn of the Court. The farm is located some 5 km south of the Brendon Hills, with land rising to 170 m immediately to the south-west. The rain gauge was in the garden with good exposure to all directions except the east, while the thermometer was mounted on the north-facing wall of a stone-built outhouse. The Wellington site is a suburban garden, the thermometer screen being partly shaded by trees during the afternoon, with the rain gauge situated so as to comply with standard exposure criteria. The site slopes gently downwards towards the north, with the north-facing escarpment of the Blackdown Hills only 2 km away to the south. When the Wellington data series began, there was arable farmland within 100 m of the site, but housing developments since the mid-1990s mean that the nearest open countryside is now more than 400 m away. Whether this has had an effect on the local climate is impossible to say.

DATA USED IN THIS STUDY

Crucial for this study have been the actual daily reports of the weather at Nettlecombe Court. These were recorded in the "Pocket Register for Climatological Observations" (Metform 3100) beginning in June 1968 and running until the end of August 2007, when pencil and paper were replaced by an electronic reporting system. In addition, from the UKMO archives, the more or less complete Nettlecombe data series have been provided for temperatures and rainfall. Interruptions to the Nettlecombe series have become more common since electronic recording commenced, but there is a sufficient overlap of the records from Wellington and Nettlecombe for missing values to be estimated, when necessary, with a high degree of confidence.

From the autumn of 2014, the Nettlecombe daily report has been regularly accessed by the author via the UKMO Weather Observations Website (WOW), and selected data logged for comparative purposes. At the time of writing

(autumn 2018) weather observations at the site are also made with an Automated Weather Station (AWS), with comparisons suggesting that the AWS tends to give a slightly smaller diurnal range, but a very similar overall mean.

From Cobhay Farm, original paper records of daily temperatures and rainfall still exist from 1960 – 1970, and from 1978 – 2000; those for the missing period having regrettably been mislaid at some point in the distant past. (At this site, temperatures were recorded in Fahrenheit throughout the period, with rainfall in inches for the first ten years. Figures have been converted as necessary.) For Wellington, there are complete and constantly updated paper and digitised records of daily temperatures and rainfall since the spring of 1987, including tables of averages and extremes during the period of the records.

The three sets of data from these recording sites, all overlapping to some extent, have enabled the construction of a detailed picture of the variations in weather and climate in a relatively small area, and during more than half a century. Some daily rainfall data from other sites in West Somerset have been included in the analyses, while further information on monthly temperatures and rainfall has been gleaned from freely accessible pages on the UKMO website. Of these, monthly data from the climate stations at Minehead on the coast of west Somerset, and at RNAS Yeovilton in the comparatively land-locked lowlands of south-east Somerset demonstrate clearly some of the contrasts in climate that exist across the region as a whole. (See Appendix A)

During this paper's four-year production period a number of climatological records for the area have been broken, entailing the amendment of certain data lists. Where reasonably practicable, some data up to and including 2018 have also been included in the production of graphs.

TEMPERATURE

Mean Air Temperature

Unsurprisingly, the mean air temperatures (MATs) for each of the three sites in this study are very similar, the 1971 - 2000 figures for Nettlecombe Court and Cobhay Farm being 9.8°C and 9.9°C respectively, and representative of the area. For the period 1981 – 2010 the Nettlecombe figure had increased to 10.1°C, the same as calculated for the Wellington site. As data were not recorded at the Wellington site for the first six years of this reference period, approximate (but probably fairly reliable) MATs were produced by extrapolating backwards in time, using the 13 year-long overlap with records from the farm.

Table 1 shows the average monthly temperatures for the entire Nettlecombe data series. In the case of months with incomplete or missing data, a figure has been estimated by weighting data from one or both of the other recording sites. In a statistical population containing some six hundred individual months, these estimated values are unlikely to have affected the overall accuracy of the representative figures. Table 1 shows that, for the Nettlecombe series, February was the coldest month and July the warmest, giving a mean annual temperature range of 11.0°C. For the period of comparable records from Nettlecombe and Wellington (1987 – 2018), we find the mean diurnal temperature at Nettlecombe to be about 1°C higher in mid-winter and 1.5°C cooler in mid-summer than at Wellington. Also, at Nettlecombe there is a slower rate of warming in spring, and of cooling in autumn. This may be attributed to the proximity of the Bristol Channel, where the sea surface temperature on average peaks in early September; it is normally at its lowest in February, and in May is often still cooler than in December.

TABLE 1. Nettlecombe Court: mean monthly temperatures 1969 – 2018.

	Mean Max. Temp. °C	Mean Min. Temp. °C	Mean Air Temp. °C	Diurnal Range °C	Std. Dev'n (MAT)	Highest MAT °C	Year	Lowest MAT °C	Year
Jan	8.2	2.2	5.2	6.0	1.8	**7.7**	1990	**1.0**	1979
Feb	8.1	1.8	4.9	6.3	1.9	**8.2**	1990	**-1.1**	1986
Mar	10.3	2.8	6.5	7.5	1.3	**8.7**	1981	**3.1**	2013
Apr	12.8	3.9	8.3	8.9	1.1	**11.7**	2011	**5.6**	1986
May	15.9	6.5	11.2	9.4	0.9	**13.1**	2008	**9.0**	1996
Jun	18.7	9.1	13.9	9.6	1.0	**16.0**	1976	**11.1**	1972
Jul	20.8	11.1	15.9	9.7	1.0	**18.7**	1983	**13.8**	1980
Aug	20.5	11.1	15.8	9.4	1.1	**18.4**	1995	**13.5**	1986
Sep	18.1	9.2	13.7	8.9	1.1	**16.3**	2006	**10.2**	1986
Oct	14.7	7.3	11.0	7.4	1.4	**13.6**	2001	**7.6**	1993
Nov	11.1	4.4	7.8	6.7	1.3	**10.9**	2015	**4.6**	1985
Dec	8.9	2.7	5.8	6.2	1.8	**11.1**	2015	**0.9**	2010
Year	**14.0**	**6.0**	**10.0**	**8.0**	**1.3**	**11.0**	**2014**	**8.6**	**1986**

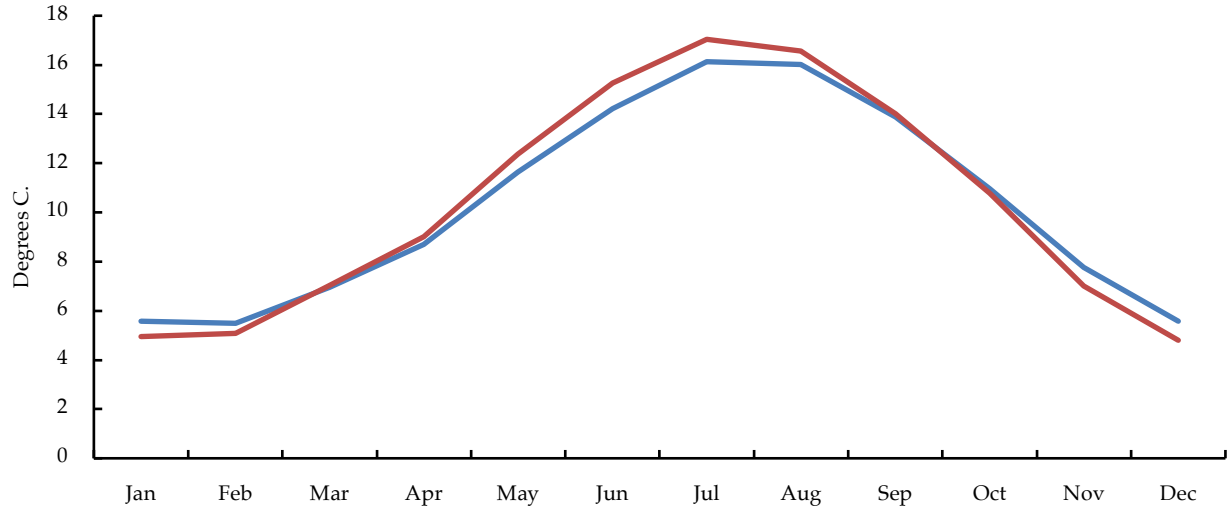

FIGURE 2. Comparison of monthly mean temperatures at Nettlecombe and Wellington, 1987 – 2016; Nettlecombe (**blue**) and Wellington (**red**).

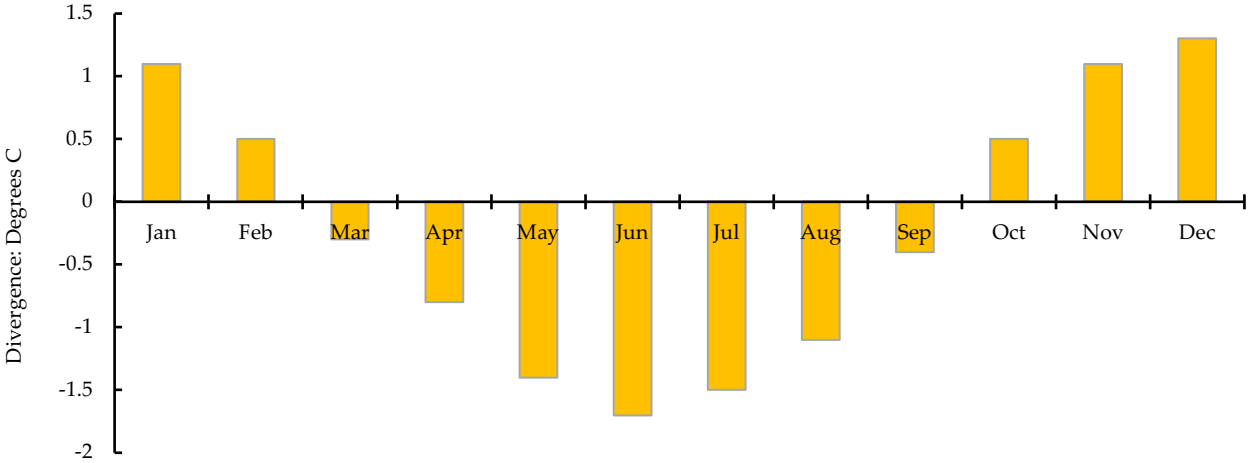

FIGURE 3. Monthly mean maximum temperatures: divergence of Nettlecombe from Wellington.

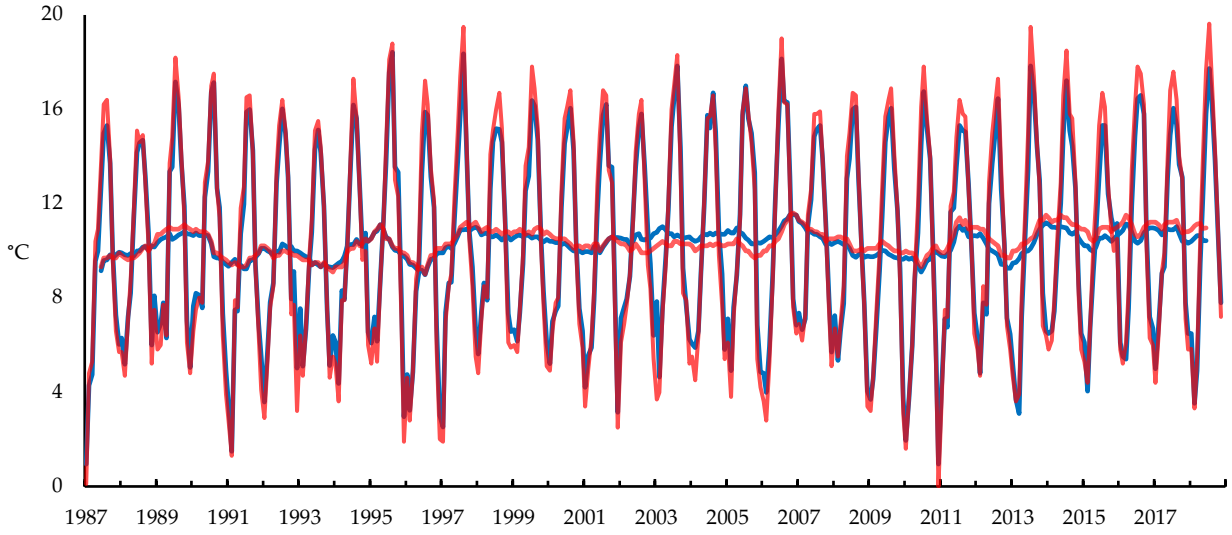

FIGURE 4. Monthly mean temperatures and 12-month running mean, 1987 – 2018: Nettlecombe and Wellington; Nettlecombe (**blue**) and Wellington (**red**).

This slight maritime influence is illustrated in Figure 2, the graph comparing monthly mean temperatures at the Nettlecombe and Wellington sites for the period 1987 to 2017. It would appear that Wellington's inland position, in a lowland area fringed by hills, results in a visibly more "continental" temperature curve. Figure 3 emphasises this in illustrating the deviation of monthly mean maxima at Nettlecombe from those recorded at the Wellington site during the same period. The greatest positive anomaly is in December, and the greatest negative one in June[2].

Table 1 also shows the highest and lowest recorded mean air temperatures for each month of the year, with the year of occurrence. Some months that achieved national notoriety appear in the lists, such as June 1976, July 1983 and the Decembers of 2010 and 2015. 1986 stands out as containing four months that were the coldest of their ilk in the Nettlecombe series and were all coldest or second-coldest on record in south-west England. However, some other "record" months at Nettlecombe failed even to achieve Top Three status in the region as a whole during the period covered by this study, demonstrating the absolute necessity to set every claim for a new climatic record within its proper context in time and space. (A scientific discipline that is rarely practised in the popular media, it would appear.)

Further analysis of monthly temperatures at Nettlecombe, Wellington and Yeovilton during the present century has revealed some puzzling facts. Between 2002 and 2006, the monthly mean at Nettlecombe was often relatively high compared with the other two sites, in relation to the long-term (1981 – 2010) average. During the first six years of this century, the Wellington data often showed the strongest negative divergence from the overall regional pattern. After a period of months when the patterns of deviation from the mean were fairly consistent across all three sites under scrutiny, Wellington took over as the site most frequently showing a positive divergence, a pattern that has persisted. During this later period, both Yeovilton and Nettlecombe had months with data showing a negative divergence from the regional data, sometimes in clusters, this being very marked for Yeovilton for much of 2015. (The apparent discrepancies between Nettlecombe and Wellington are identifiable in the 12-month running means of absolute values shown in Figure 4.)

Reasons for these rather haphazard patterns are not easy to identify. There is no evidence of incomplete data being behind the discrepancies. In the case of both Yeovilton and Nettlecombe, instrumentation has to conform to UKMO standards, and it is unlikely that local factors affecting the site have altered significantly. The Nettlecombe "warm phase" therefore remains a puzzle. At Wellington, the same thermometers and screen have been in use, in the same position, throughout the period in question. It is however possible that the growth of trees in neighbouring gardens has created a more enclosed space, reducing air movement and causing higher temperature readings. Records show that the increasing frequency of relatively high minima is the main factor in raising the mean values. However, under conditions favourable for frost, it can still get almost as cold here as at a known rural frost hollow some five kilometres away. That a small urban "heat island" exists in the centre of Wellington, about one kilometre away, has been noticed and commented on by local acquaintances of the author.

Diurnal Mean Temperatures

The graphs in Figure 5 show in detail the fluctuation of diurnal mean temperatures through the year at Nettlecombe and at Wellington, for the twenty-nine years 1988 to 2016. (Significant interruptions in the records for 2017 at Nettlecombe prevented the creation of a full thirty-year base-line period for comparative purposes.) Together Figures 5A and 5B demonstrate clearly the patterns of seasonal change, and the differences between the temperature regimes at the two sites. The relative coolness of Nettlecombe during the summer half of the year is clearly indicated, but with mean temperatures being generally higher there than at Wellington from mid-October to the end of February. As previously mentioned, this is likely to be an effect of the site's relative proximity to the sea.

Looking in detail at the data, we find that on average the coldest week of the year at both sites begins on January 22nd, while at Wellington July 20th marks the start of the warmest week. At Nettlecombe, however, the warmest week starts almost a fortnight later. At neither site are the seasonal changes very smooth. Figure 5a suggests that early February is often warmer than early March, with this latter period including the coldest night of the winter in some years during the present century. It is, however, followed by the year's most marked spell of rapid warming, the mean temperature rising by 2.5°C in a fortnight, before relapsing briefly about the time of the Vernal Equinox.

The short-lived cool spell at the beginning of April seems to be a genuine long-term climatic feature, borne out by memories of bitter weather returning after unseasonable warmth in late March, such as in 1965 and 1968 (with heavy snowfall in the latter case), as well as many more instances recorded in recent years. One possible explanation is that a general reduction in the strength of the circumpolar circulation in early spring may allow the incursion over Britain of both mild air from the near continent, and a final taste of winter from the North Pole. The second half of April sees a marked acceleration in the advance of spring, with a subsequent slightly erratic increase in temperatures until late-July. Perhaps worthy of further investigation is the counter-intuitive 1°C drop in mean diurnal temperatures around the time of the Summer Solstice.

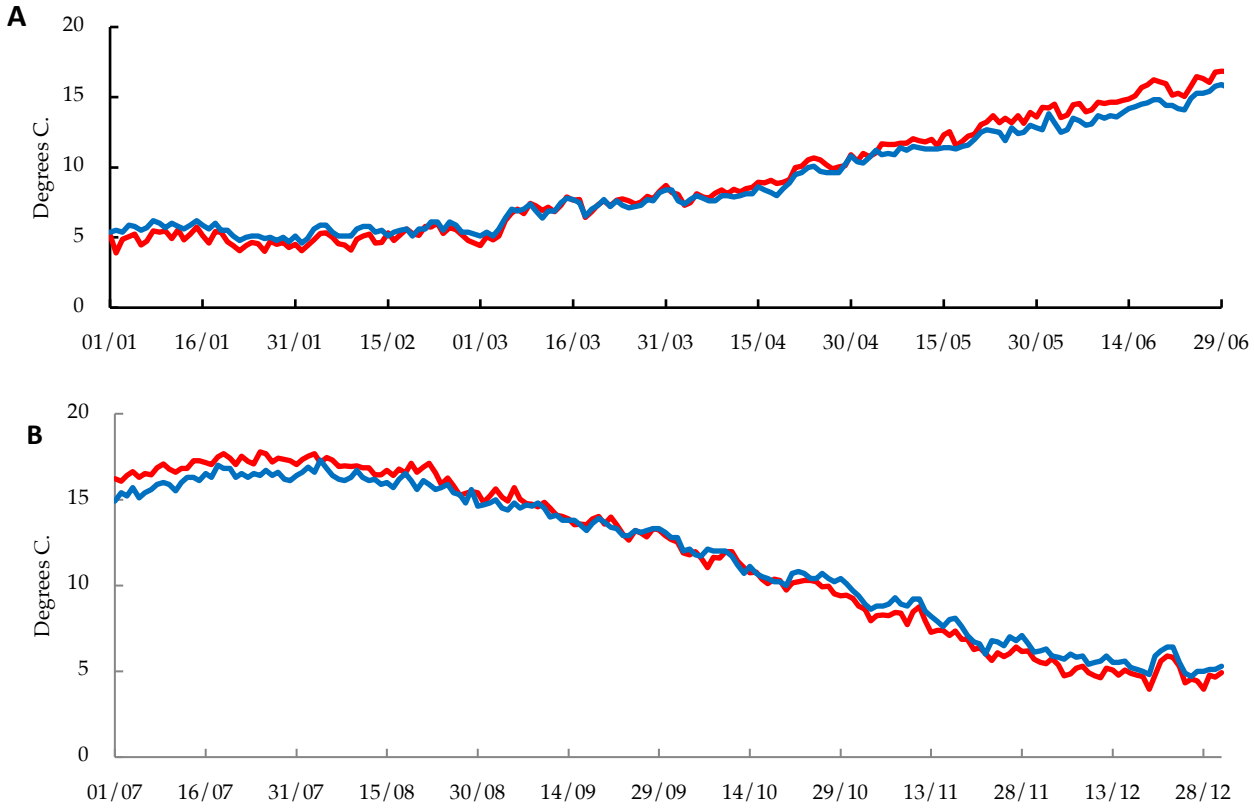

FIGURE 5. Diurnal mean temperatures at Nettlecombe (**blue**) and Wellington (**red**) for reference period 1988 – 2016: **A** January-June; **B** July-December.

Figure 5B shows that at both sites there is a steady cooling during September and October, but this becomes more erratic through November and December, with a remarkable recovery of temperatures in the week before Christmas. There is no obvious explanation for this, although the daily weather records suggest that this particular period has often been characterised by cyclonic conditions, with significant rainfall and warm winds from the south-west. Decembers have been generally much warmer than average since the severely cold one in 2010, and the records show that the warmest day in the month has occurred during that third week every other year, on average. Temperatures fall abruptly after Christmas but tend to recover in early January before subsiding later in the month, as noted above. Notably mild nights (≥ 9°C) are only half as common in February as in January, probably attributable to a progressive cooling of the waters around the South-West Peninsula in late winter.

Together, the graphs suggest that, in the lowland area as a whole, the mean temperature may be expected to remain above 6°C from the first week of March to the last week of November, and above 10°C from the third week of April to the end of October. These values are generally accepted, respectively, as marking the lower threshold for grass growth and for the germination of maize, a crop that has become significant in the region in recent decades.

Annual Mean Temperatures

Figure 6 shows the annual mean maximum and minimum temperatures, and the 10-year running mean, at Nettlecombe from 1969 onwards. Not surprisingly, the patterns are broadly paralleled by those for Yeovilton and Wellington, with individual notably warm or cool years being easily identified. The at-the-time record warm spell of 1989 – 90 is very distinct, followed by the slight cooling in the early 1990s (perhaps attributable to the global climatic impact of the 1991 eruption of Mount Pinatubo). Overall, there has been a detectable upward trend in both maximum and minimum temperatures since the late 1980s, the graph showing quite clearly the period of consistent warmth from 1997 to 2006. Since then the curve has been more erratic, with the coolest recent year (2010) quite out of step with the times.

Figure 7 illustrates the deviation of annual mean temperatures from the 1971 – 2000 mean, emphasising the warming tendency in recent years. The mean temperature for 2010 was arguably reduced by 0.4°C by the coldest December on record, while in 2013 a notably cold March had a similar but lesser effect, partly offset by the very hot July that followed. Conversely, the relatively cool summer of 2011 did not prevent that becoming (at the time) the warmest year on record. Although 2006 seems to mark the peak of a period of warming, with a slight downward trend since then,

the decadal average temperature for the most recent part of the series is still considerably higher than it was in the mid-1980s. (The value for 2017 has been estimated by appropriate weighting of the Wellington data, for those months when records for Nettlecombe were interrupted.)

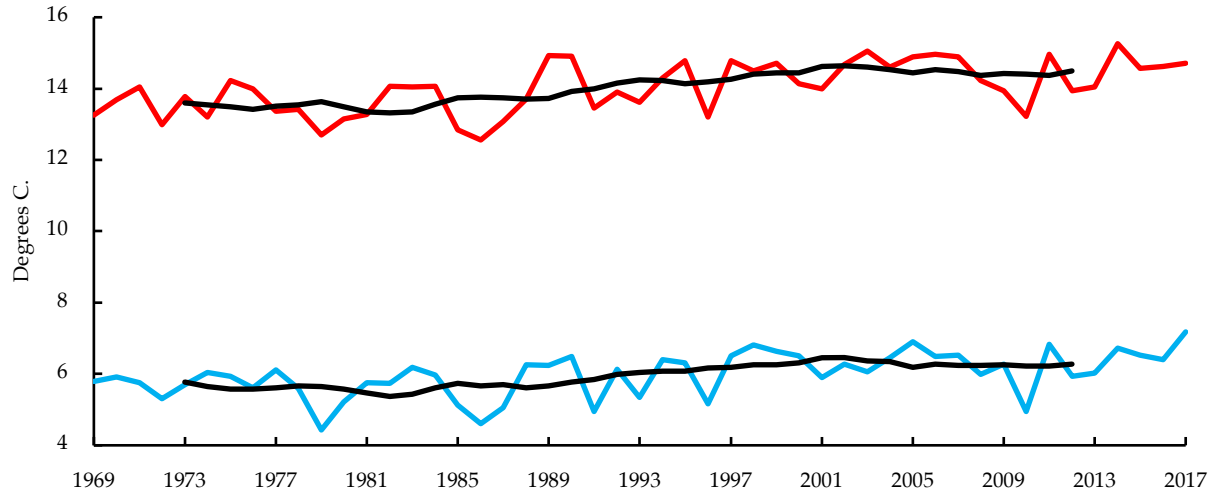

FIGURE 6. Nettlecombe Court: annual mean maximum (**red**) and minimum temperatures (**blue**) 1969 – 2017, and 10-year running means.

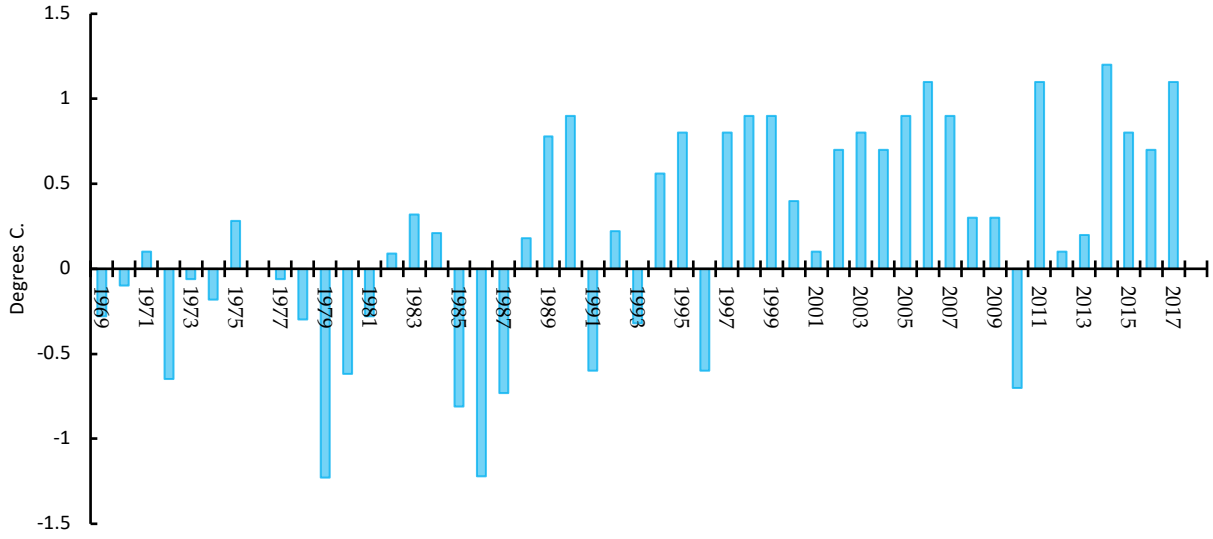

FIGURE 7. Nettlecombe Court: deviation of annual mean temperatures from 1971 – 2000 mean.

The Seasons

"When is the first day of summer?" seems to be a question that cannot be answered to everybody's satisfaction. Taking the slightly arbitrary value of 21°C (70°F) as one which most would agree as being "summery", the data for Nettlecombe (and during the last thirty years, for Wellington) display a remarkable range of dates when this temperature was first recorded in the year. For Nettlecombe, the earliest date was April 14th, in 2007, and the latest was July 14th, in 1972. The mean date for that threshold at Nettlecombe for the whole series is May 18th, but, breaking up the series, we find it to have been May 20th for the period 1971 – 2000 and May 12th for the present century to date. Looking also at the latest dates each year with a maximum of 21°C or more, we find that the mean date is now September 18th, compared with September 13th in the earlier period. Again, there has been a wide fluctuation between individual years, the earliest being July 16th in 1986 and the latest October 12th in 1978 and 1990. These findings imply that, on average, "summer" is arguably almost two weeks longer now than it used to be. This pattern is reflected in the data for Wellington, the mean earliest date being four days earlier than at Nettlecombe and the latest date two days later.

A similar analysis of the date of the first air frost of autumn also shows a significant change over the decades (see Figure 8). Comparisons between the data sets for Nettlecombe, Wellington and Cobhay show a consistency in the occurrence of this event across the area as a whole. For the latter two sites, the mean date for the baseline period 1961 – 1990 was October 24th, compared with November 9th in the first eighteen years of the present century. On this basis, the onset of "autumn" would seem to be now about a fortnight later than it was in the latter part of the 20th century. Whichever way one chooses to analyse the seasonal climate data for the sites in this study, evidence for change is revealed. This is true if one looks also at the data for individual calendar months.

The graphs in Figure 9 provide detailed information about the fluctuations of monthly mean temperatures at Nettlecombe to the autumn of 2018. Since the mid-1980s there has been a slight increase in the frequency of hot summer months, scattered rather randomly through the series. Winters in the 1970s were generally on the mild side, cooling at the end of that decade, the 1980s then being characterised by wide variations in winter temperatures. Nothing previously in the records compared with the remarkably mild winter of 1988/89, having a mean temperature of 7.2°C. Since then, there have been four more winters with no month averaging below 6°C. Up to the end of 2016 the warmest 12-month period on record was July 2006 to June 2007 with a mean temperature of 11.5°C, closely followed by the same period in 2013-14. These patterns are reflected in Figure 10, illustrating in a highly visual way all significant monthly mean temperature anomalies at Nettlecombe since the establishment of the climate station there.

Tables 2A and 2B provide data regarding mean temperatures at Nettlecombe for the four seasons. Table 2A gives decadal averages as well as providing values for the whole data series, with a notable increase of 0.8°C in the annual mean temperature between 1971–80 and 2001–10. Among other things, the table highlights the colder winters of the 1980s, and rapid overall warming in the 1990s. This was especially marked during winter and spring. For the decade 2001 – 2010, winters appear to have cooled again, once again explained by the exceptionally cold December in 2010 lowering the average, with a marked recovery in winter temperatures since then. The most significant change in recent years has been the warming up of autumn, with an increase of 0.9°C in mean maximum temperature between the 1990s and the 2000s.

The changes in the character of the seasons over time are reflected in Table 2B, showing the top five and bottom five ranked seasons and years in the Nettlecombe data series up to and including 2018. Taking an overview of the entire data series, one can see that most of the notably warm seasons have been in the second half of the period, with all five of the warmest autumns and years occurring from 2005 onwards[3]. In contrast, most of the notably cold seasons occurred in the first half of the Nettlecombe data series, the winter of 2010/11 and the spring of 2013 standing out as major exceptions.

These records show that climate change, however it may normally be manifesting itself, does not mean the total disappearance of lengthy spells of unusually cold weather. (See below.) However, analysis of the data leads to the conclusion that in all seasons, months with higher-than-average mean minimum temperatures would appear to characterise the 21st century. New record mean minima have been set for seven months of the year, sometimes by a significant margin (notably, + 2.8°C in December 2015). These patterns are not restricted to Nettlecombe, being paralleled by those observed at the Wellington site and reflected, though slightly less strongly, by data from Yeovilton.

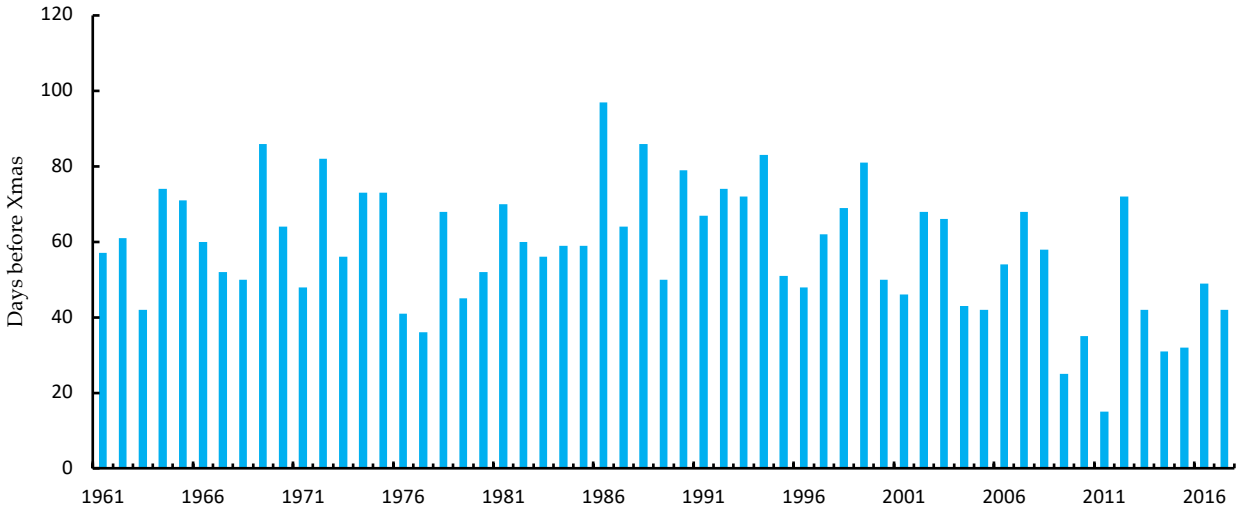

FIGURE 8. Occurrence of first air frost in Wellington area: days before Christmas.
(Day 20 = Dec 5th; Day 40 = Nov 15th; Day 60 = Oct 26th; Day 80 = Oct 6th)

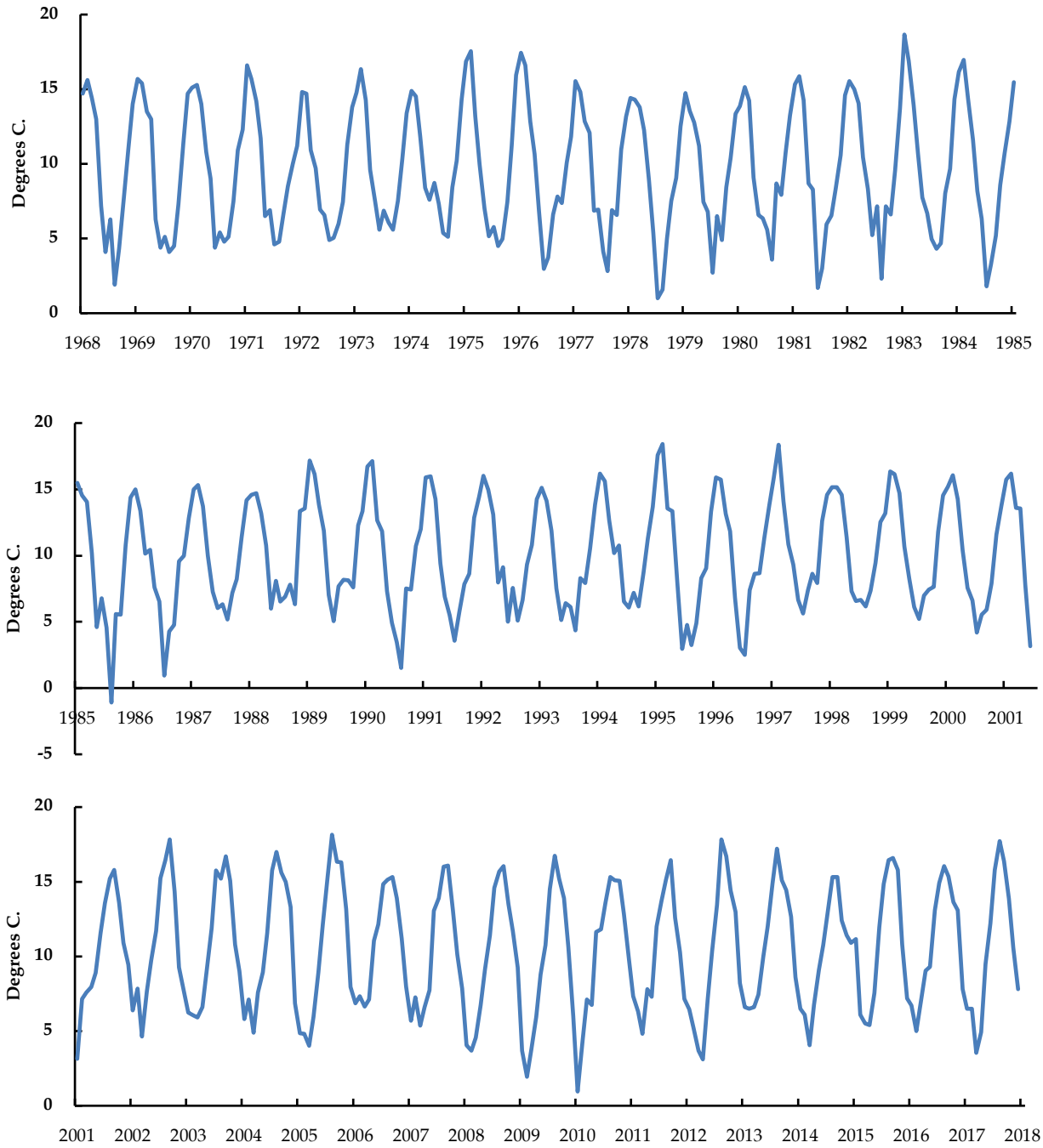

FIGURE 9. Nettlecombe Court: monthly mean temperatures, July 1968 – November 2018.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1968	x	x	x	x	x	x						
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	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	**4.9**	**4.9**	**6.6**	**8.0**	**10.9**	**13.5**	**15.8**	**15.7**	**13.3**	**10.5**	**7.5**	**5.8**
SD	**1.6**	**2.0**	**1.4**	**0.9**	**1.0**	**1.0**	**1.1**	**1.3**	**1.1**	**1.3**	**1.2**	**1.5**

Cooler	**1.0-1.4 SD**	**1.5-1.9 SD**	**2.0-2.4 SD**	**2.5 SD +**
Warmer	**1.0-1.4 SD**	**1.5-1.9 SD**	**2.0-2.4 SD**	**2.5 SD +**

FIGURE 10. Monthly mean temperature deviations at Nettlecombe. (Standard Deviations from the 1971 - 2000 mean).

TABLE 2. Nettlecombe Court: seasonal temperatures ^{0}C. (A) mean diurnal, mean maximum and mean minimum temperature. (B) Warmest and coldest seasons and Years (where **1** is warmest and **50** the coldest)

A

Mean diurnal temperature ^{0}C

Decade	Winter	Spring	Summer	Autumn	**Year**
1970s	5.2	8.0	14.6	10.3	**9.5**
1980s	5.0	8.4	15.1	10.4	**9.7**
1990s	5.4	9.1	15.3	10.6	**10.1**
2000s	5.2	9.2	15.7	11.3	**10.3**
2011-2018	*6.2*	*9.0*	*15.5*	*11.5*	***10.6***
Whole Series	**5.4**	**8.7**	**15.2**	**10.8**	***10.0***

Mean maximum temperature ^{0}C

Decade	Winter	Spring	Summer	Autumn	**Year**
1970s	8.1	12.1	19.4	14.1	**13.4**
1980s	8.0	12.7	19.9	14.2	**13.7**
1990s	8.6	13.2	20.2	14.4	**14.1**
2000s	8.5	13.6	20.4	15.3	**14.5**
2011-2018	*9.3*	*13.5*	*20.2*	*15.2*	***14.6***
Whole Series	**8.5**	**13.0**	**20.0**	**14.6**	**14.0**

Mean minimum temperature ^{0}C

Decade	Winter	Spring	Summer	Autumn	**Year**
1970s	2.3	3.8	9.9	6.4	**5.6**
1980s	2.0	4.1	10.3	6.7	**5.8**
1990s	2.2	4.9	10.3	6.9	**6.1**
2000s	1.9	4.7	11.0	7.3	**6.2**
2011-2018	*3.0*	*4.5*	*10.8*	*7.8*	***6.5***
Whole Series	**2.3**	**4.4**	**10.5**	**7.0**	**6.0**

B

Rank	Winter	Spring	Summer	Autumn	Year
1	7.6 (2015/16)	10.2 (2011)	16.7 (1976)	12.6 (2011)	11.0 (2014)
2	7.2 (1988/89)	10.1 (2007)	16.6 (2018)	12.5 (2006)	10.9 (2011)
3	7.1 (1974/75)	10.0 (2017)	16.6 (2006)	11.9 (2014)	10.8 (2006)
4	7.0 (1998/99)	9.8 (2014)	16.6 (1995)	11.9 (2013)	10.7 (2005)
5	7.0 (2006/07)	9.8 (1999)	16.5 (2003)	11.7 (2005)	10.7 (2007)
46	3.6 (1995/96)	7.5 (1984)	14.1 (1980)	9.6 (1985)	9.1 (1973)
47	3.4 (1985/86)	7.4 (1996)	14.1 (1977)	9.4 (1986)	9.1 (2010)
48	3.3 (1990/91)	7.3 (1986)	14.0 (1978)	9.3 (1974)	9.0 (1985)
49	3.1 (2010/11)	7.2 (1979)	13.6 (1979)	9.2 (1972)	8.6 (1979)
50	2.7 (1978/79)	6.9 (2013)	13.5 (1972)	8.2 (1993)	8.6 (1986)

Hot and Cold Spells

The local climate records naturally reflect the notable spells of heat and cold that affected England in the latter part of the past century. In common with much of the region, the weather in the area covered by this study is normally very changeable. Partly because of the topography, even a slight shift of wind direction can result in very different conditions on a day-to-day basis. A study of the daily records shows that throughout the 1960s and early 1970s genuinely hot days occurred infrequently and usually in ones and twos. For the entire Nettlecombe data series, there were on average thirty-six days a year when a temperature of 21°C or higher was recorded, and just seven days with a

temperature of 25°C or more. That latter value was not reached even once in the summers of 1972, 1978, 1980 and 1993. From the Cobhay Farm records we can add to the list both 1962 and 1965, while in 1963 no daily maximum even as high as 21°C was recorded there between August 6th and September 16th.

In the search for the rare hot spells in the early part of the data series for Cobhay Farm, the ten days ending on September 3rd 1961 stand out, with a mean maximum of 25°C and a memorable 29°C on September 2nd. After that, July 1964 included three successive days above 25°C, while July 1967 was one of the warmest months in the decade, including a fortnight with maxima ≥ 21°C and the decade's highest maximum of 30°C. 1969 was the first full calendar year with weather records for Nettlecombe. July in that year was warmer than average but without any sustained hot spell, while the subsequent five summers offered little by way of heat. Figure 11 shows the annual total numbers of days with maxima ≥ 21°C, and those with maxima ≥ 25°C, highlighting the very great variability from year to year, and suggesting a slight increase with the passage of time.

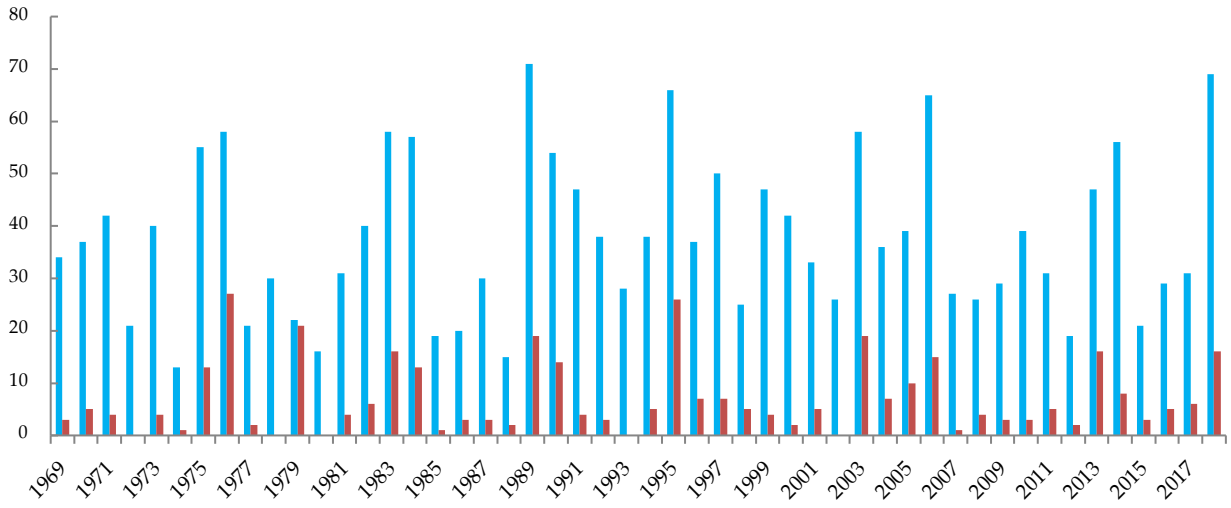


FIGURE 11. Nettlecombe Court annual total numbers of daily maxima ≥ 21°C (blue) and ≥ 25°C (red).

The summer of 1975 was remarkable for including several spells of exceptionally hot, sunny weather, most notably the fortnight ending on August 9th. With a mean daily maximum of almost 26°C, and five successive days exceeding 28°C, this outclassed any previous hot spell in the Nettlecombe and Cobhay Farm combined series. It would however be itself eclipsed in the summer of 1976, which contained two separate three-week periods with no daily maximum below 21°C at Nettlecombe, and twelve successive days spanning late June and early July with maxima above 26°C. That record remains unchallenged, although July 1983 contained a nine-day spell with maxima ≥ 26°C in an unbroken thirty-day period with maxima ≥ 21°C. However, the longest spell with maxima above the latter threshold value lasted from July 23rd to August 26th 1995, a period of thirty-five days. (At that time in Wellington, the continuous period with maxima ≥ 21°C lasted for fifty-three days, with two spells of more than a week with daily maxima ≥ 26°C. This can be seen as an instance of the greater "continentality" of the site manifesting itself.)

In more recent years, comparable prolonged spells of hot weather have been noticeably absent, despite a significant increase in mean summer temperatures. This is chiefly attributable to the greater frequency of relatively high minima. At Nettlecombe, August 2003 contained a memorable week with a mean maximum of 26.8C, July 2006 contained eleven days in succession with maxima ≥ 25°C, and in 2013 all but three days between July 7th and 23rd had maxima ≥ 25°C. However, no summer in the present century has included six successive days with maxima ≥ 26°C at Nettlecombe. While July 2014 included an eighteen-day spell with maxima above 21°C, the hot days were few and scattered through the period[4].

It is appropriate at this point to reflect on the exceptional summer of 2018. Although available data suggest that it was only second-warmest on record at Nettlecombe (after 1976: Table 2b), for the region as a whole it was the warmest. At Wellington, the overall mean temperature of 18.2°C for June, July and August was the highest on record and more than 2°C above the 1981 – 2010 mean. Perhaps of equal significance, at that site the mean of 15.6°C for the six-month period April – September 2018 was also a record, with 2006 and 2014 in second and third positions. This was also the case at Yeovilton, and while significant interruptions in the recordings at Nettlecombe for those years prevented the calculation of accurate figures, the same pattern seems very probable there.

Periods of notable warmth at other seasons seem to have become more frequent with the passing of time. They were noticeably absent during the 1960s, and although the Octobers of 1968 and 1969 both contained unusually warm

spells, the next period to be worthy of note was the winter of 1974/75, which was frost-free at Nettlecombe from October 13th to January 16th. Among other notable spells of winter warmth was the first half of January 1998, including two of the three warmest January days ever recorded at the site. February in that year was also very mild, the last three weeks having a mean diurnal temperature of 8.1°C, slightly below the normal for April and including a record-breaking spell with maxima as high as 18.0°C. January 2007 saw eighteen days in succession with a maximum ≥ 10°C, including seven above 13.0°C, the same number as occurred in the first twenty-five years of the Nettlecombe records.

Most recently, in 2015, there was a noteworthy 42-day spell commencing on November 23rd with no daily maximum at Nettlecombe below 10°C. As in 1974, December 2015 was entirely frost-free there, with a remarkable temperature of 15.5°C on December 17th. A comparison of the data from the different sites during these winter warm spells reveals that maxima at Nettlecombe were on average more than a degree higher than at Wellington. The records indicate that prevailing winds at the time were predominantly from between south and west, so adiabatic warming was very probably a contributory factor at Nettlecombe.

Notable warm spells in spring were also almost entirely absent during the first twenty years of records at Nettlecombe. Although March 1972 included six successive days with maxima of 15.5°C or higher, no other March offered anything to approach that until 1990, when there was a week with a mean maximum of almost 15°C, peaking at 18.5°C on March 17th. March 1997 and 1999 also included warm spells, but they did not compare with ten-day spells in March 2003 and 2005 with daily maxima averaging higher than 15°C. Eclipsing these was the memorable ten-day spell in late March 2012, with a mean daily maximum of 16.8°C and the highest ever March reading at Nettlecombe (20.0°C)

As for April, in those first twenty years at Nettlecombe, on only ten days in total was 20°C reached or exceeded during that month. Not until 1987 did April offer memorable sustained warmth, the second half of the month having a mean daily maximum of 17.3°C, 4.6°C above the whole-series average. Unsurprisingly, that month set a new record for the highest April mean maximum (14.5°C) to be surpassed in 2003 (15.1°C), again in 2007 (16.8°C) and finally in 2011 (an estimated not less than 17.2°C, based on other regional data). In each of these last three years, April included clusters of unusually warm days, while in 2015 the fortnight ending on April 25th had a mean daily maximum of 16.7°C, without containing any notably warm days. Hot spells in May have been rather rare, a notable week ending on May 6th 1990 having a mean daily maximum of 23.0°C at Nettlecombe (and 24.5°C in Wellington). May 2008 was the warmest on record, with a mean maximum at Nettlecombe of 21.4°C for the ten-day period ending on May 13th. In each of 1989, 1992, 2010 and 2012 the second half of May included a spell with four or five days reaching 24°C. Placing that in context, in six of the first ten years of the Nettlecombe records, the highest temperature in May was below 21°C, the first instance of a May maximum of 24°C or higher being in 1982.

While the recent remarkable warming up of autumn has already been noted, there were instances of an unusual extension to summer in the earlier years of the Nettlecombe records. A week in October 1978 had a mean maximum of 20.4°C, peaking at 24.3°C on 12th, the latest recorded date for such a temperature at the site. In both 1981 and 1982, the first ten days in September had mean maxima above 21°C. Notably warm spells in September were then infrequent until the turn of the century, with the Septembers of 2003, 2004, 2005 and 2006 each containing a ten-day period with daily maxima averaging 22°C or higher. Unseasonably warm autumn weeks have occurred in other recent years, most notably in 2011, with a mean daily maximum of 24.4°C at Nettlecombe for the seven-day period ending on October 3rd. (A maximum of 26.6°C on October 2nd was not only by a wide margin the highest temperature recorded at the site in October but was also the maximum for that year as a whole.) All these examples of notable autumn warmth were recorded across much of England, being associated with anticyclones centred over the near continent or the North Sea drawing up air of Mediterranean origin.

Not surprisingly in the light of the discussion above, long spells of notably cold weather seem to have become rarer. At Cobhay Farm, the second half of December 1961 included six days with sub-zero maxima, and night-time minima as low as -8°C. The overall mean temperature there for the three weeks ending on January 5th 1962 was -1.4°C. However, the cold weather benchmark was established by the winter of 1962 – 63. Between December 23rd 1962 and January 25th 1963, at Cobhay Farm, there were twenty-eight daily maxima ≤ 0°C, with night-time minima falling as low as -12°C. Subsequent observations at other sites would suggest that these conditions would have been fairly representative of the area as a whole.

The following ten winters all contained cold months, the most extreme spell being twelve days in January 1966, including six daily maxima below 0°C and having a mean temperature of -0.6°C at Cobhay Farm. The next noteworthy period was not until 1978, when February included a fortnight with a mean diurnal temperature of -0.5°C at Nettlecombe, and -1.5°C at Cobhay Farm. The winter of 1979 was unusually cold. At both sites, the first ten days of January had a sub-zero mean, while between February 2nd and 18th inclusive no daily maximum above 4°C was recorded, although severe frosts were few in number.

Looking at the 1980s, December 1981 included twelve successive nights with air frost at Nettlecombe, while in 1985 January had nineteen and February eleven. February 1986 saw the start of the most sustained cold spell since 1963, twenty-seven days ending on March 4th. The temperature fell below freezing on every night during that period, giving a mean air minimum of -4.2°C, with four days having a sub-zero maximum. In that same year, April, August and

September were also abnormally cold (effectively more than a month out of step with the calendar). The last air frost occurred on April 27th, and the first ground frost on August 5th, followed by an unparalleled score of fourteen ground frosts in September.

There were periods of roughly three weeks' duration with sub-zero diurnal means in the winters of 1987, 1991, 1996 and 1997. There was then significant interlude without notable cold spells, until 2010. That year began with a fortnight having a mean of -0.5°C at Nettlecombe, while it ended by setting a new record for duration and intensity of cold at the site. The 33-day spell ending on December 27th included the all-time extreme minimum for the month (-9.0°C) and just two individual nights without an air frost. The mean minimum air temperature for this period was only marginally higher than that for the February 1986 "big chill". In Wellington during the same period there were eight days with maxima ≤ 0°C, compared with two at Nettlecombe, and an extreme minimum of -11.6°C.

The only other noteworthy cold spell of the present century to date was the fifteen days ending on April 7th 2013, with a mean diurnal temperature at Nettlecombe of 1.6°C (about 6°C below normal), and an air frost on every night. In all the previous springs in the Nettlecombe records, there has been nothing to approach that[5].

Temperature Extremes

It was noted very early in the life of the Nettlecombe climate station that the effects of local topography occasionally result in some surprising extremes of diurnal temperature for a site that is not very far from the sea. Table 3A and 3B show the absolute extremes of temperature recorded at Nettlecombe since the site came into operation. Although January 13th 1987 is generally regarded as the coldest day on record in South-West England, at Nettlecombe it was the previous day, with a maximum of -6.0°C. In common with most other inland sites in the UKMO South-West District, both Nettlecombe and Yeovilton recorded their absolute extreme minimum temperature on January 14th 1982: -13.4°C and -16.1°C respectively (the latter being the lowest air temperature ever recorded at an official site in Somerset). At Cobhay Farm, -13°C was recorded on January 1st 1979. The records show five other occurrences of an air minimum below -10°C at Nettlecombe, including that date, but with none since February 1991[6]. The hottest day on record in the south-west as a whole was August 3rd 1990, when the all-time extreme maximum of 33.3°C was recorded at Nettlecombe, a rare example of it being hotter there than at Wellington. In some respects, it is surprising that Yeovilton's county record maximum of 34.5°C on that day was not even higher.

TABLE 3. Nettlecombe Court: absolute extreme temperatures 1969 – 2018; (A) Decadal absolute extreme maxima °C; and (B) Decadal absolute extreme minima °C. Figures in **bold** type indicate all-time monthly records. Figures in *italics* estimated from Wellington data.

3A. MAX	1971-80	Year	1981-90	Year	1991-00	Year	2001-10	Year	2011-18	Year
Jan	13.1	1974	13.7	1983	**14.8**	1998	14.4	2003	**14.8**	2015
Feb	13.0	1976	14.9	1990	**18.0**	1998	16.4	2004	13.2	2011
Mar	18.5	1977	18.5	1990	16.7	1998	17.5	2005	**20.0**	2012
Apr	21.1	1975	22.6	1990	21.5	1994	23.8*	2003	**24.0**	2018
May	23.7	1980	25.5	1989	24.2	1997	**25.7**	2003	24.0	2018
Jun	**30.7**	1976	28.7	1986	28.7	1995	29.5	2005	30.4	2017
Jul	**32.3**	1976	30.2	1983	29.1	1996	30.7	2003	30.2	2016
Aug	30.8	1976	**33.3**	1990	31.6	1995	31.5	2003	*28.0*	2013
Sep	24.2	1973	**26.1**	1982	24.5	2000	25.4	2005	25.5	2011
Oct	24.3	1978	22.1	1985	23.2	1997	20.7	2008	**26.6**	2011
Nov	16.7	1978	16.7	1990	17.1	1992	17.1	2005	**17.5**	2015
Dec	15.4	1977	**16.4**	1985	15.4	1994	15.0	2007	15.5	2015

3B. MIN	1971-80	Year	1981-90	Year	1991-00	Year	2001-10	Year	2011-18	Year
Jan	-10.5	1979	**-13.4**	1982	-7.5	1992	-9.0	2009	-6.5	2016
Feb	-8.2	1978	-9.1	1985	**-11.2**	1991	-6.5	2008	-8.7	2018
Mar	-7.5	1971	**-8.8**	1986	-3.5	1993	-7.0	2010	-5.6	2018
Apr	-3.7	1980	**-4.4**	1990	-3.1	1996	-3.5	2008	-4.0	2013
May	-1.2	1979	**-2.2**	1982	-1.2	1996	-1.0	2010	0.0	2016
Jun	1.5	1977	1.5	1987	**0.8**	1991	3.3	2001	1.7	2015
Jul	3.9	1979	5.0	1984	4.7	1993	**3.5**	2008	4.5	2015
Aug	**3.0**	1980	4.3	1987	3.4	1993	5.0	2003	4.0	2014
Sep	0.8	1972	**0.1**	1986	1.0	1993	1.0	2003	1.0	2018
Oct	-2.2	1972	-2.2	1988	**-5.5**	1993	-3.1	2003	-3.5	2018
Nov	-8.0	1973	-5.6	1983	**-9.0**	1993	-8.2	2010	-6.2	2016
Dec	-6.8	1976	-7.8	1981	-6.0	1999	**-9.0**	2010	-5.0	2014

The tables show that certain years seem to have more than their fair share of appearances in the lists, in particular 1990 and 2003 for high temperatures (5 listings) and 1993 for low ones (6 listings). Looking at Table 3A, the figures suggest no increase in extreme summer temperatures, with the all-time records occurring more than twenty-five years ago. However, with the exception of December, the highest recorded temperatures for each month from October to May have all occurred since 1990. In the case of January, at Nettlecombe there was no daily maximum higher than 13.7°C from 1969 until 1998. The remarkable reading of 14.8°C in that year was equalled in January 2015, with eight other instances of a temperature of 14°C or higher in the intervening period. These may all be specifically attributed to the adiabatic warming of a moist airflow from the south or south-west descending the northern face of the Brendon Hills. The entire coastal strip including Minehead, Blue Anchor and Watchet can enjoy significant winter sunshine under such conditions, enhancing the warming effect, with some amateur observers in the area reporting temperatures around 16°C in the first week of December 2016. This phenomenon is noted by Perry (1997).

TABLE 4. Nettlecombe Court: Monthly average extremes of maximum (4A) and minimum (4B) temperature.

4A.	MAXIMUM	J	F	M	A	M	J	J	A	S	O	N	D	Year
(a)	Whole series	12.7	12.5	15.2	18.2	22.0	24.8	26.2	25.5	22.5	19.1	15.7	13.5	**19.0**
(b)	1969 - 2000	12.5	12.3	14.8	18.0	21.5	24.8	25.9	25.8	22.4	18.8	15.6	13.6	**18.8**
(c)	2001 onwards	13.4	12.9	15.9	18.4	23.0	24.7	26.8	24.8	22.8	19.8	16.0	13.4	**19.3**
	Difference (c) - (b)	0.9	0.6	1.1	0.4	1.5	-0.1	0.9	-1.0	0.4	1.0	0.4	-0.2	**0.5**

4B.	MINIMUM	J	F	M	A	M	J	J	A	S	O	N	D	Year
(a)	Whole series	-5.1	-4.2	-3.3	-2.1	0.8	3.7	6.0	5.9	3.3	0.3	-3.1	-4.1	**-0.2**
(b)	1969 - 2000	-5.3	-4.0	-3.2	-2.4	0.6	3.3	5.9	5.8	3.1	0.0	-3.4	-4.0	**-0.3**
(c)	2001 onwards	-4.8	-4.5	-3.4	-1.5	1.2	4.4	6.2	6.2	3.4	1.0	-2.7	-4.3	**0.1**
	Difference (c) - (b)	0.5	-0.5	-0.2	0.9	0.6	1.1	0.3	0.4	0.3	1.0	0.7	-0.3	**0.4**

The same cause was probably responsible for an unusually high March maximum of 18.5°C at Nettlecombe in 1977, and again in 1990. The Blackdown Hills clearly had a similar effect on the temperature in Wellington in the latter instance, 18.7°C being at the time the record for March at that site. The all-time extreme maxima for March at both sites (20°C and 21°C respectively), set in 2012, occurred during a week of almost unbroken sunshine associated with an anticyclone centred over the UK.

It should be noted that the 23.8°C at Nettlecombe listed for April 2003 is less than the extraordinary reading of 27.5°C on the previous day, April 16th (as it appears in both Metform 3100 and in the UKMO data series). This must have been incorrectly observed, as, if accurate, it would have been the highest April temperature recorded at a site anywhere in Britain for more than fifty years. Nettlecombe's all-time April maximum of 24.0C on April 21st 2018 occurred in a brief nationwide heat-wave, so one can be fairly confident that under the exceptional conditions in April 2011 similar temperatures may well have occurred. Unfortunately, there was an equipment failure that left a gap in the records over that period.

Another example of extreme heat that went unrecorded at Nettlecombe was in July 2013, when improbably high readings were attributed to a thermometer fault or human interference, and not recorded. In fact, unusual atmospheric conditions appear to have led to extremely high temperatures across much of west Somerset at the time, with a maximum of 32°C in Wellington, while an unofficial (and highly suspect) site in Taunton claimed 35°C. The Nettlecombe thermometer seemed to have returned to normal functioning after a few days. 30.2°C is therefore listed as the highest verifiable July maximum for the decade to date.

The data in Table 3B suggest that, in spite of other signs of a general warming of the climate, there is little overall change in the monthly extreme minimum temperatures recorded at Nettlecombe. Certain years, such as 1993, appear frequently in the table, although more surprising are the four listings for 2018, overall a warm year with spells of noteworthy heat. In fact, one cold spell produced the low readings for both February and March, while brief incursions of Arctic air resulted in the unusually low minima in September and October, both months being otherwise very mild.

That the daily recordings at Nettlecombe have over the years been carried out by a large number of untrained observers leaves some data open to question. Definitely to be regarded with suspicion is a short series of air minimum temperatures as low as -8°C recorded at Nettlecombe in April 1980, as indicated by the daily entries in Metform 3100. The readings are not consistent with the grass minimum temperatures recorded at the site on those days and are at odds with records of only very slight frosts at Cobhay Farm[7]. However, in early April 1990, air minima below -4°C at Nettlecombe are consistent with readings at the Wellington site, with a grass minimum of -11.5°C on April 9th being

extraordinarily low for the time of year. This was a very quiet, anticyclonic spell of weather, with a gentle flow of air from the east and little if any cloud.

Table 4 shows the average extreme maxima and minima at Nettlecombe for each month. The patterns are very similar to those indicated by data for Cobhay Farm (up to the end of the year 2000) and for Wellington. Detailed analysis of the data reveals a greatly increased frequency of notably mild days in late winter and early spring during the present century. If we include in the analysis the daily temperature records from Cobhay Farm for the 1960s and 1970s, we find that, for example, a March maximum of 16°C or higher occurred once every three years on average. So far in the 21st century (including March 2018) there have been thirty-nine instances of that at the Wellington site. The total number of recent March maxima ≥16°C at Nettlecombe is slightly lower at twenty-seven, compared with just ten instances in the previous thirty years (and five of those occurring in the same unusually warm spell in March 1972).

Interestingly, the ranked "noteworthy" lists for the Wellington area show that really hot summer days (≥ 28°C) are much rarer now than in the 1980s and 1990s. This decrease is particularly marked for August (and detectable in Table 4A), while July has consistently contained at least one notably hot day every other year on average. The common public perception that our summers are not as "good" as previously may in part be attributed to the run of rather dull Augusts in recent years, which would account for the current rarity of notably hot days in the month. For June, on the other hand, this recent period has included months near the top of the sunshine rankings[8] as well as ones that were near the bottom. However, there is a weaker correlation between mean temperature and sunshine in that month, June 2016 being remarkably dull but much warmer overall than the very sunny June of 2015. In Wellington, June 2017 was at the time the warmest since 1976, and included the hottest June day since that year, at 32.0°C. Even so, total hours of sunshine for the month were below average. (The month fell during another period when daily maximum temperatures were not being recorded at Nettlecombe.) June 2018 rivalled June 1976 for warmth and, more predictably perhaps, was unusually sunny.

The data in Table 4B suggest that while there has been no great change in the degree of cold that is possible in winter at Nettlecombe, unseasonably chilly nights in the summer half of the year would appear to be less frequent. Detailed analysis of the data from both sites supports this conclusion. There has also been a significant decrease in the average annual number of air frosts at Nettlecombe (screen minimum ≤ 0°C), from 45 in the last two decades of the 20th century, to 37 in the period since the millennium. (Remove the severe winter of 2010-11 from the calculation and the latter figure falls to 33.) Figure 12 shows the patterns of decrease at the Nettlecombe and Wellington sites to be very similar, which is not surprising, given that atmospheric conditions likely to give rise to a frost are known to apply on a regional rather than local scale.

In parallel with this, the relative frequency of nights that are notably cold has also decreased in the region. Figure 13 shows the number of occurrences of an air minimum temperature of -4°C or lower for each year in the Nettlecombe series[9]. In spite of the very obvious spike in 2010, the overall trend would appear to be downwards. Analysis of the relevant data from the Cobhay Farm and Wellington sites, which show a strong correlation during the thirteen-year overlap period, suggests a steeper decline at these more inland sites.

A comparison of daily temperatures at Cobhay and at Nettlecombe for selected winters in the 1960s and 1970s also shows a close correlation between minima on very cold nights. Daily records from Cobhay for the winters 1960/61 to 1969/70 give a mean annual number of 16 nights with a minimum of -4°C or lower. Remove the winter of 1962/63 from the calculation and the mean reduces to 13, which figure seems to have stayed much the same to the end of the century. For the period 1987 – 2000 in Wellington, air temperatures fell to -4°C or below on average 11 times a year. Since 2001 the figure stands at just 7 a year (the same as for Nettlecombe), even though the period has included three winters that were more than 1°C colder than average, with December 2010 being the coldest on record and having thirteen daily minima of -4°C or lower at both sites.

As has been noted above, there is strong evidence that a significant component in the apparent warming of the local climate is the generally higher minimum temperatures. Notably mild nights have become much more numerous in the area during the present century, and a new record high diurnal minimum has been set for nine of the twelve months in the year. Figure 14 shows the pattern of increase in the annual number of nights with a minimum of 10°C or higher. For the period since the year 2000, in the Wellington area the mean is almost 100, compared with 81 during the previous twenty years. At Nettlecombe the equivalent values are 89 as against 77.

An analysis of their distribution month by month shows that they are relatively more common in the latter part of the year at Nettlecombe than at Wellington, while at both sites they are least frequent in March and April. In some years the 10°C high minimum threshold is not reached before the middle of May. At both sites the highest April minimum on record is below that for December, and for Nettlecombe the highest recorded monthly minimum is above that for Wellington for each month from October to April inclusive. It is reasonable to assume that the rarity of warm nights in spring is at least in part a result of the relative coolness of the sea surface around the South-West Peninsula, while extra adiabatic warming probably accounts for the higher readings at Nettlecombe during the winter half of the year.

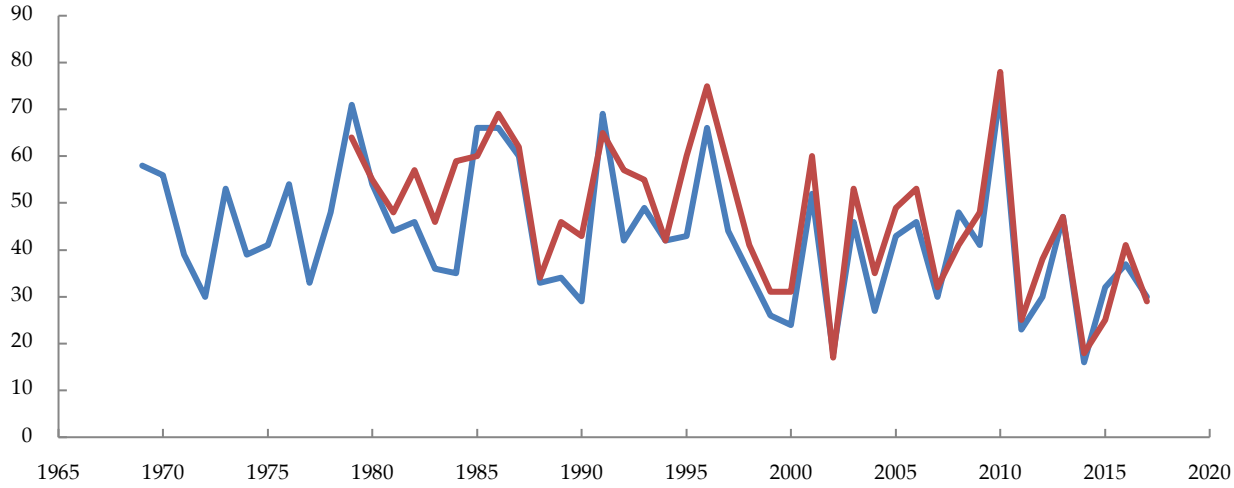


FIGURE 12. Annual total numbers of air frosts: Nettlecombe (**blue**) and Wellington area (**red**).

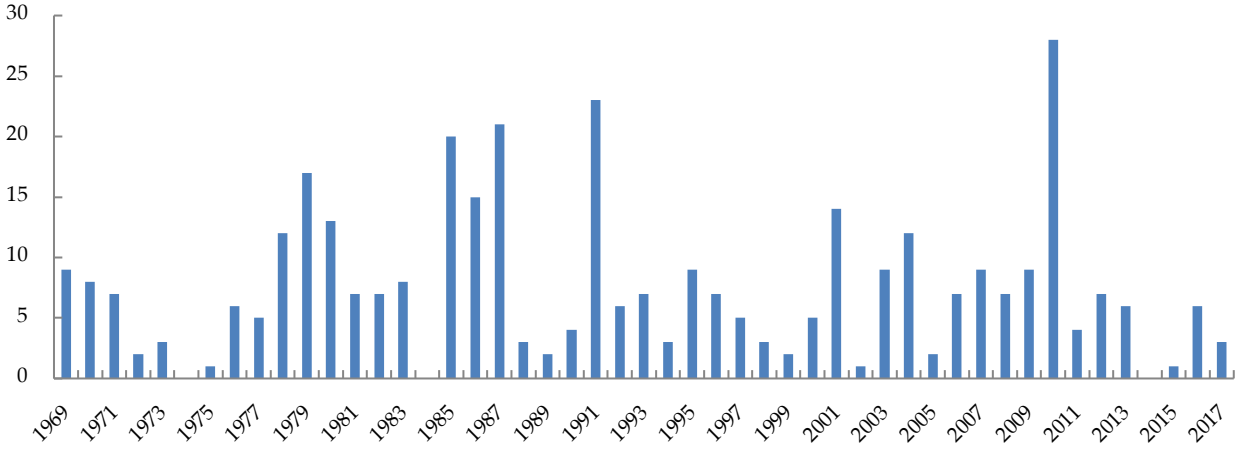


FIGURE 13. Nettlecombe Court: Annual total numbers of daily minima, -4⁰C or lower.

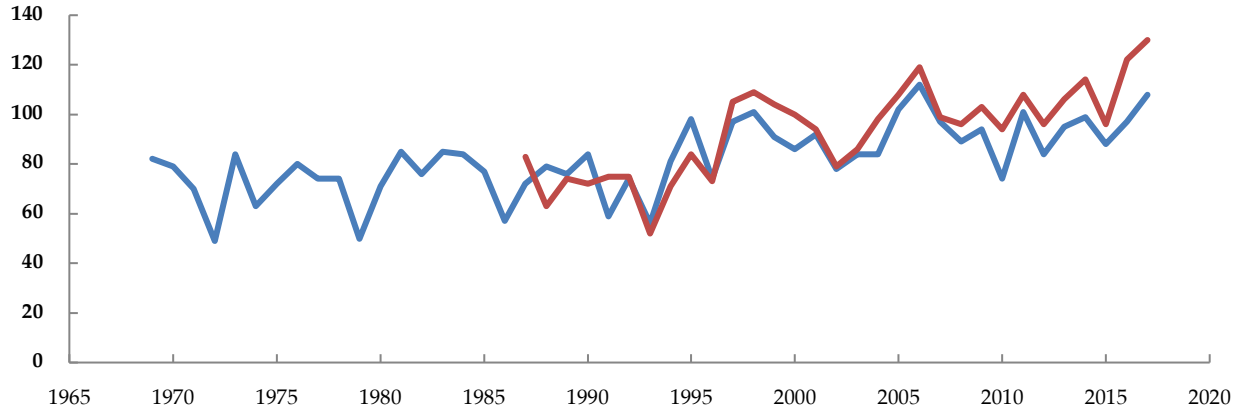


FIGURE 14. Annual total numbers of daily minima, 10C or higher: Nettlecombe (**blue**) and Wellington (**red**).

Range of temperature

Scrutiny of Nettlecombe's daily temperature records spanning half a century reveals that a surprisingly wide diurnal range is possible, considering the proximity of the site to the coast. A diurnal range of 14°C can occur there under certain circumstances in December, January and February, and seems to be most frequently associated with a change of

air mass, as a warm front arrives after a cold spell. A comparison of data from Wellington and Nettlecombe for the same dates in these months shows a generally greater diurnal range at Nettlecombe, usually because of higher maximum temperatures: +1.3°C on average, in the case of December (See Appendix A). This may be partly explained by the influence of the still relatively warm Bristol Channel, as well as adiabatic warming.

From mid-March, as insolation increases, diurnal ranges at both Nettlecombe and Wellington increase rapidly. At this time, the waters of the Bristol Channel are relatively cold, so maxima at Nettlecombe tend to be lower than at Wellington. However, the Nettlecombe "sun trap" can lead to some extraordinary extremes in spring, as when the temperature rose from 4.1°C to 23.8°C on April 17th 2003, in a notably hot, sunny spell that produced a very early crop of apple blossom in the area. Under more normal circumstances, a diurnal range of 17°C in April and 18°C in May would be considered noteworthy. The greatest recorded diurnal ranges at both sites occurred in July, but not in the same year. At Wellington, July 25th 1995 saw the temperature rise by 23.6°C (from 5.8°C to 29.4°C), compared with a rise of 21.0°C, from 8.0°C to 29.0°C, at Nettlecombe. The following year, a marginally greater range was recorded at Nettlecombe, from 7.9°C to 29.1°C on July 22nd. Comparative figures at Wellington were 8.4°C and 30.0°C. Allowing for possible slight errors in reading by different observers on the two dates (as indicated by the handwriting in Metform 3100), one can say with a reasonable degree of confidence that under ideal conditions the probable extreme diurnal range at Nettlecombe is >21°C. Weather conditions were remarkably similar on both occasions cited above, being anticyclonic with prolonged sunshine, clear skies overnight, and a light southerly breeze at 1000 BST when the observations were made. Soil conditions were very dry, so no heat was being lost to evaporation.

From August onwards, the potential for extreme ranges at Nettlecombe is once more reduced, the relative warmth of the waters of the Bristol Channel generally helping to keep minima slightly higher. However, calm, clear anticyclonic conditions have been known to lead to the night-time development of a significant katabatic air-flow down the Nettlecombe valley, with a ground frost possible at the weather station site in any month of the summer. This may account for several instances of an unusually wide range of temperature occurring in late August and September. By this time of year, the site's early local sunset (about 1800 hrs BST) can lead to rapid cooling by radiation under clear skies, only for unbroken strong sunshine the following day to lift temperatures rapidly. Good examples are 18.0°C on August 29th/30th 1979 (4.9°C to 22.9°C) and 17.7°C on September 10th/11th 1985 (5.4°C to 23.1°C). As with the extreme ranges occurring in July, soil conditions were recorded as being very dry at the time.

With the advance of autumn, the warming influence of the Bristol Channel seems to become progressively more pronounced, by day and by night. Sea surface temperatures there have been as high as 18°C in some recent summers and still around 17°C at the end of September. Although the record-breaking hot spell at the beginning of October 2011 included a diurnal range of 16.8°C, under normal conditions the extreme values at Nettlecombe for October and November are <13°C. They always seem to be the result of the change of air mass described above.

TABLE 5. Nettlecombe Court: monthly range of temperature.

	1970-2000					2001-2017			
	Mean Max.	Mean Min.	MAT	**Range**		Mean Max.	Mean Min.	MAT	**Range**
Jan	7.9	1.9	4.9	**6.0**	Jan	8.7	2.5	5.6	**6.2**
Feb	8.0	1.8	4.9	**6.2**	Feb	8.7	2.0	5.4	**6.7**
Mar	10.2	3.0	6.6	**7.2**	Mar	10.8	2.6	6.7	**8.2**
Apr	12.2	3.6	7.9	**8.6**	Apr	13.8	4.3	9.0	**9.5**
May	15.6	6.2	10.9	**9.4**	May	16.5	7.0	11.8	**9.5**
Jun	18.3	8.8	13.6	**9.5**	Jun	19.2	9.8	14.5	**9.4**
Jul	20.7	10.9	15.8	**9.8**	Jul	20.9	11.4	16.2	**9.5**
Aug	20.5	10.8	15.7	**9.7**	Aug	20.3	11.5	15.9	**8.8**
Sep	17.8	9.0	13.4	**8.8**	Sep	18.7	9.5	14.1	**9.2**
Oct	14.2	6.7	10.5	**7.5**	Oct	15.3	8.2	11.7	**7.1**
Nov	10.8	4.1	7.5	**6.7**	Nov	11.7	4.9	8.3	**6.8**
Dec	8.8	2.9	5.9	**5.9**	Dec	9.2	2.6	5.9	**6.6**
Year	**13.8**	**5.8**	**9.8**	**7.9**	**Year**	**14.5**	**6.4**	**10.4**	**8.1**

Of some interest in this context are the observed changes in monthly mean values of diurnal temperature range at Nettlecombe during first seventeen years of the present century, compared with the means for the previous thirty years (See Table 5). The overall change of a modest +0.2°C masks some significant seasonal changes. Every month except August shows an increase in mean maximum (+1.6°C in the case of April), while only March and December show a reduction in mean minimum, with the extremely low temperatures of March 2013 and December 2010 slightly skewing

the results. Collectively, the three autumn months show a 0.9°C increase in both mean maximum and mean minimum, the mean diurnal range staying unchanged at 7.7°C. The biggest increases in diurnal range are in March and April, while June, July and August show a decrease in range. In the case of June, the 0.9°C increase in mean maximum is offset by a 1.0°C increase in mean minimum, while August has the most significantly reduced diurnal range, now being the month with the highest mean minimum.

There is no obvious explanation, although the relatively frequent occurrence of sunny springs and cloudy summers in the 21st century so far may be a contributory factor. Referring again to sunshine records from Yeovilton and allowing for a change in the method of recording in the summer of 2003, there appears to have been a significant 21st century increase in the average number of hours of sunshine in April, compared with the period from the start of that data series in 1983 to the year 2000. The same data suggest an even greater decrease in the average for August during the present century. The very strong autumn warming signal at Nettlecombe, noted above, might well be attributable in part to higher sea surface temperatures enhancing the seasonal temperature time-lag, so that mean maxima remain relatively high through December and January. The effect appears to have worn off by February, with that month's mean minimum being the lowest, whichever sampling period is taken.

A further research project might be to establish whether the effect of higher winter sea temperatures in the Bristol Channel is more to raise daytime temperatures, rather than to prevent the occurrence of frost by night. Again, we encounter the intriguing balance between the relative influences of local topography and proximity to the sea, together creating the very distinctive, and possibly unique, local climate experienced at Nettlecombe Court.

RAINFALL

The recording sites in their regional context

It has long been recognised that patterns of rainfall in south-west England are strongly influenced by topography, to the extent that the dominant areas of upland (e.g. above 300 metres ASL) can be easily identified on any precipitation map. This is true at a smaller scale also. With the focus of this paper being "lowland west Somerset", it is important to bear in mind that this term embraces an area of very varied topography, with land in places rising to heights of more than 150 metres above sea level. Even these comparatively modest differences in altitude are often reflected in variations in both mean precipitation and the character of individual falls of rain, as indicated by rainfall records that have been maintained for various periods of time at several different sites in the area in question.

For Nettlecombe Court, there was available for this study an almost unbroken daily rainfall record from the summer of 1968 to the autumn of 2012, but with some significant gaps since then. Probable monthly totals have been interpolated where data were missing. (Reference has also been made to sample data from the former UKMO recording site on Bird's Hill, 2 km south of Nettlecombe Court and at an altitude of 273 metres.) For Cobhay Farm, where non-standard rain gauges were used, the daily records on paper are extant for the periods 1964 – 1970 and 1978 – 2000, with an uninterrupted monthly total data series from 1962 to 2000. For Wellington, the current daily data series began in April 1987, with no significant interruptions. Also available were the daily data from an official recording site at Sampford Brett about 3km north-east of Nettlecombe, for 1961 to 2014 inclusive. A relatively short daily series (1972 – 1978) was provided by a UKMO-registered amateur observer then living at Chipley, 3 km south-east of Cobhay Farm. With several periods of overlap, these sets of data have allowed the creation of a fairly clear picture of the normal variations of precipitation within the study area, over more than half a century, and of the nature and distribution of extreme rainfall events. (See Figure 1 for location of sites.)

Annual Rainfall

Figure 15 shows the annual rainfall totals at Nettlecombe from 1969, the first full year of observations at the site. These figures are placed within a wider areal context in Figure 16a, comparing annual rainfall at Nettlecombe with that recorded at Yeovilton, and, from 1987, at Wellington. Interestingly, 1973 appears as the driest year in the Nettlecombe series although it is not remembered as such[10], being soon followed by 1975 and 1976 with their spectacularly hot, dry summers. From the late 1970s to the mid-1990s there were no particularly wet or dry years, with 1994 being the wettest year in the Nettlecombe series up until then. Following the very dry summer of 1995 there was a significantly wetter phase that peaked in the year 2000. The mean annual total for the five-year period ending 2002 was 118% of the mean for the period 1981 – 2010. Equivalent values for Wellington and Yeovilton were respectively 117% and 120%. Other sources suggest that this was the wettest such period in England since the start of the UKMO data series in 1910.

During the present century, annual rainfall totals have exhibited greater variability than previously, the coefficient of variation having increased to 19.7% compared with 16.0% for the whole series. 2010 and 2011 comprised the pair of years with the lowest combined total in the Nettlecombe series, and this seems to be true for Southern England as a whole, with no drier pair of years on record in more than a century. At Nettlecombe, 2012 and 2014 were wettest and third wettest respectively, the 2012 total possibly being greater than depicted in the graph. No daily rainfall record

exists for Nettlecombe during December of that year, and the 200 mm monthly total interpolated from other data sets may well be a conservative figure. For both Yeovilton and Wellington, 2012 was the wettest year on record by a significant margin.

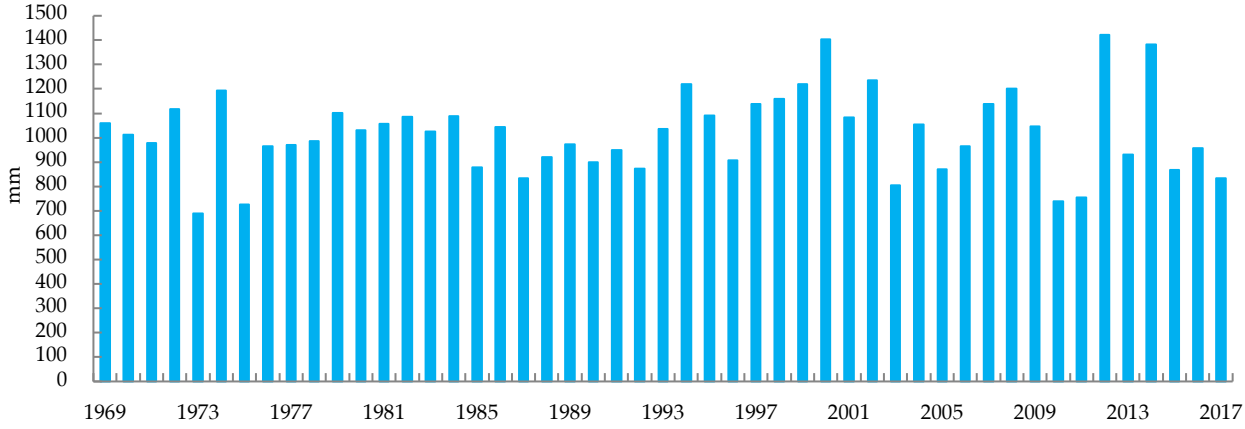


FIGURE 15. Nettlecombe Court: Annual Rainfall Totals 1969 - 2017.

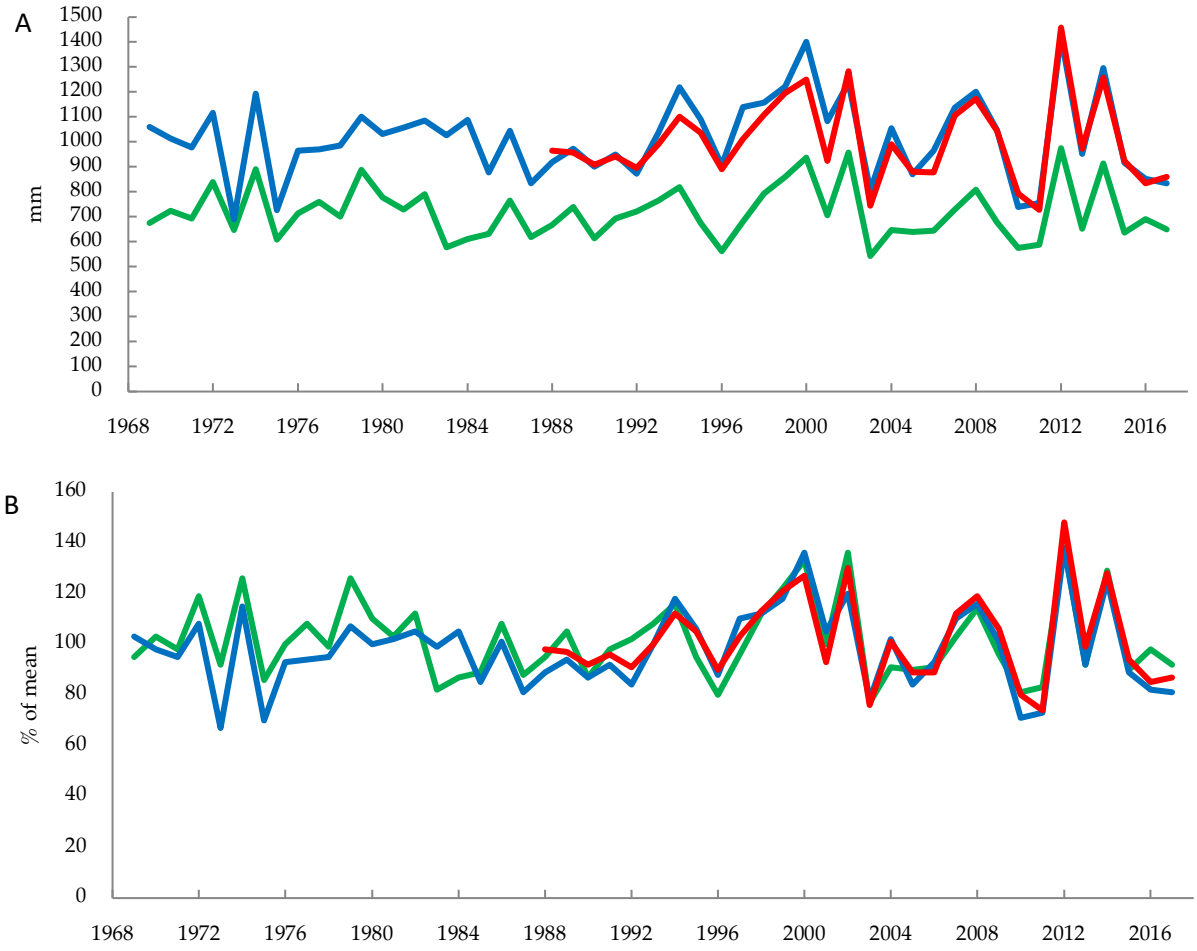


FIGURE 16. Comparison of annual rainfall totals at three sites in Somerset; Nettlecombe (**blue**), Yeovilton (**green**) and Wellington (**red**). (A). Annual Rainfall Totals 1969 - 2017; (B). Annual Rainfall Totals as % of the 1981 - 2010 mean.

Figure 16B changes numerical values to percentages, allowing a direct comparison between the same three recording sites. It is of interest that from 1969 to 1994, Yeovilton was more often wetter-than-average than was Nettlecombe, sometimes by a significant margin, but with much less divergence since then. The added curve for the Wellington data accords closely with the other two curves, much as one might expect. On the understanding that there were no changes in siting or exposure of rain gauges at the two official sites, the implication seems to be that since the mid-1990s there has been a relatively greater change in the rainfall regime at Nettlecombe than at Yeovilton[11].

Further detailed analysis of the available local data suggests a small and erratic increase in total rainfall with the passage of time. At Cobhay Farm the mean for the 1961 – 1990 reference period was 1032 mm, increasing to 1069 mm for the period 1971 - 2000. Nettlecombe's annual mean had increased from 1018 mm for 1971 – 2000 to 1033 mm for 1981 – 2010, and to 1043 mm for the period 1991 - 2017. Rainfall data from other sites in England suggest this to have been a widespread pattern of change, an increase from the late 1980s being observed at Slapton Ley in south Devon (Burt and Horton, 2001) and continuing through the late 1990s, as indicated by the records kept at Malham Tarn in north Yorkshire (Burt and Horton, 2003). However, data for Yeovilton show a 2.7% reduction in mean annual rainfall for the current UKMO reference period 1981 – 2010, compared with 1971 – 2000, but with a slight increase detectable in the present century. There may in fact be no overall trend, with both 2016 and 2017 having been noticeably dry across the region, and the mean annual rainfall for Nettlecombe during the 21st century so far is 2% below the 1981 - 2010 mean. Data for Wellington suggest a similar slight reduction.

Monthly and Seasonal Rainfall

Table 6 summarises the Nettlecombe monthly rainfall data for the period 1969 – 2017. For the whole series, July is seen to be the driest month and January the wettest and also one of the least variable. For the current UKMO reference period 1981 – 2010, June is the driest and December the wettest. Further comparison of the mean values for individual months during the different sampling periods reveals some interesting changes. So far during the period commencing in 1991, the winter months have on average been slightly drier than was normal during the first thirty years of the data series, while March and September have been about 15% drier. The other seven months have been wetter, with the difference being most marked in July, on average a surprising 50% wetter than in the 1971 – 2000 reference period.

TABLE 6. Nettlecombe Court monthly rainfall means and deviations

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Whole series mean	123.7	88.1	77.0	63.6	65.9	59.1	58.1	68.8	75.4	108.8	112.7	121.4	1022.6
Standard Dev'n	57.5	54.9	36.3	48.3	35.4	39.9	39.9	42.3	50.1	56.1	51.3	55.6	160.4
Coefficient of Variation	46%	62%	47%	76%	54%	68%	69%	61%	66%	52%	46%	46%	16%
1971 - 2000 mean	123.6	87.6	80.5	66.3	62.6	55.7	43.4	66.5	88.4	108.6	106	128.7	1018
1981 - 2010 mean	118.4	83.6	79.1	69.5	67.2	56.0	60.7	67.3	76.2	116.8	114.8	123.1	1033
1991-2017 mean	*121.1*	*86.6*	*68.5*	*69.8*	*67.5*	*60.9*	*65.3*	*68.9*	*74.2*	*114.5*	*124.3*	*121.5*	*1043.1*

TABLE 7. Nettlecombe Court: Rainfall - monthly averages and extremes 1968-2017.

	Mean mm.	**Standard Deviation**	**Coeff. Of Variation**	**Rain days 0.1 mm or more**	**Rain/day mm.**	**Max.**	**Year**	**Min.**	**Year**
Jan	123.7	57.5	46%	20	*6.34*	249.7	*1984*	8.4	*1997*
Feb	88.1	54.9	62%	15	*5.91*	230.8	*2014*	7.5	*1986*
Mar	77.0	36.3	47%	17	*4.64*	161.9	*1982*	14.7	*1973*
Apr	63.6	48.3	76%	13	*4.78*	216.2	*2000*	2.8	*2011*
May	65.9	35.4	54%	13	*4.92*	144.3	*2008*	10.1	*1991*
Jun	59.1	39.9	68%	12	*4.80*	205.0	*2012*	7.8	*1995*
Jul	58.1	39.9	69%	11	*5.28*	185.0	*2007*	5.8	*1976*
Aug	68.8	42.3	61%	12	*5.83*	204.9	*1997*	11.7	*1998*
Sep	75.4	50.1	66%	13	*5.76*	207.4	*1976*	9.3	*1971*
Oct	108.8	56.1	52%	17	*6.55*	239.5	*2000*	6.3	*1978*
Nov	112.7	51.3	46%	19	*6.09*	217.8	*2009*	25.1	*1988*
Dec	121.4	55.6	46%	19.	*6.32*	226.2	*1993*	33.2	*1988*
Year	**1022.6**	**160.4**	**16%**	**180.**	***5.60***	**1422.3**	***2012***	**690.4**	***1973***

More information is provided by Table 7, which includes the highest and lowest rainfall totals recorded at Nettlecombe in each month since June 1968, and the year of occurrence. It will be noticed that seven of the "Wettest" months have occurred in the 21st century, and only one of the "Driest", April 2011 being the driest month of any ilk in the series. April is also shown to be statistically the most variable month, with a coefficient of variation of 76%, having been the driest month of the year at Nettlecombe ten times (or one year in five).

Figure 17 compares the mean monthly rainfall figures for Nettlecombe and Wellington during the thirty-year period ending in 2017. Nettlecombe is shown to be significantly wetter from October to February inclusive, and Wellington slightly wetter from May to September, the difference being greatest in August. Given that its position in a topographical bowl has been shown to give Wellington a slightly more continental climate, these differences are not surprising. Significantly higher summer temperatures there would be expected to result in more rainfall of a convectional nature (for which there is circumstantial evidence).

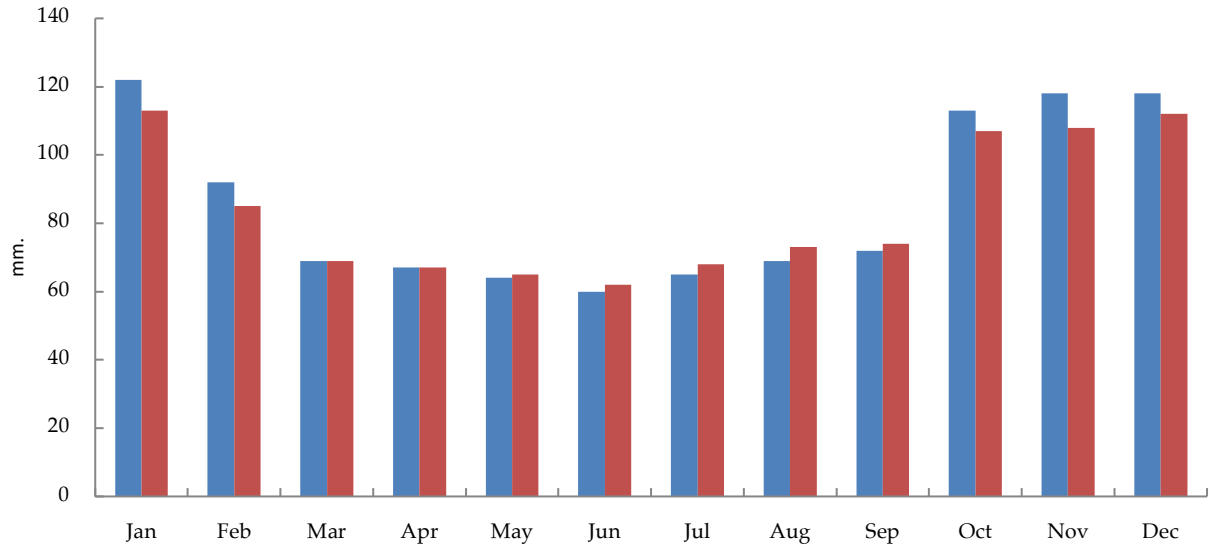


FIGURE 17. Figure 17. Mean Monthly Rainfall 1988 - 2017: Nettlecombe (**blue**) & Wellington (**red**).

Nettlecombe's position so close to a major upland area would lead one to expect the addition of an orographic element to the precipitation there, and this assumption is supported by the data. A comparison of rainfall amounts on Bird's Hill (at an altitude of 273 metres) and at Nettlecombe Court on the same days in a small sample of years shows little difference between the two, when looking at rainfall events of 20 mm or more. On one in three such occurrences (n = 43) there was more rain at the lowland site. The mean value of these heavy falls was marginally higher on Bird's Hill, but that seems true for falls of all magnitudes, and for the number of days with measurable rainfall (only about 10 more per year). One is led to the interesting conclusion that Nettlecombe Court occupies a lowland site with an upland precipitation regime. However, as noted above, under certain conditions it can enjoy the same rain shadow effect as the coastal zone between Minehead and West Quantoxhead, which in climatic terms includes Sampford Brett with a mean annual rainfall that is almost 20% lower than Nettlecombe's.

Table 8 shows the wettest and driest seasons and years recorded at Nettlecombe. For each of the four seasons, the wettest on record has occurred from the year 2000 onwards, along with the four wettest years. Of particular note is the winter of 2014, 12% wetter than its nearest rival, and almost as wet as the record-breaking three-month spell with widespread and prolonged flooding that ended the year 2000. While 2011 boasts the driest spring on record, more than half of the notably dry seasons fell during the 1970s and 1980s. Interestingly, the second driest spring (1990) followed the second wettest winter, while the spring of 2011 followed a very dry one.

In looking for any trends in the seasonal distribution of rainfall in the area, it was recognised that the combined data series since 1962 for the Wellington area gave the longest perspective, with weighting applied as necessary. Figures 18A –18D suggest that since the start of the 21st century, relatively dry autumns and winters have increased in frequency in the western part of Somerset, as have relatively wet summers, with no detectable change in spring. In general, as would be expected, the Nettlecombe curve is very similar. There are certain slight deviations, dry summers appearing to be relatively drier at Nettlecombe, and wet autumns and winters relatively wetter. These differences may reflect both the proximity of the coast and of the Brendon Hills, as discussed above.

A comparison of like-for-like periods in the Nettlecombe and Yeovilton area data series (Tables 9A and 9B) shows that the changes in rainfall patterns are not totally consistent across the region. Yeovilton, arguably more

representative of south-central England, is significantly drier than Nettlecombe at all seasons. At both sites there has been a 4 – 5% decrease in the mean winter rainfall in the present century compared with 1971 - 2000, but no significant change in its variability as represented by the coefficient of variation. For spring, the mean totals have fallen by a similar percentage, with a marked increase in variability in the 21st century at Nettlecombe. At Yeovilton the changes in spring rainfall amounts and variability are in the same direction, but more modest.

The biggest changes appear to affect summer and autumn. Nettlecombe data suggest a fairly steady increase in summer rainfall, for the most recent sampling period almost 21% above the 1971 – 2000 mean. (This is not surprising in view of the fact that it includes three of the four wettest summers in the entire series.) Figure 18C graphically demonstrates the much greater degree of variability of summer rainfall since about 1990, at both Nettlecombe and Wellington. Interestingly, at Yeovilton the summer increase is under 5%, and with the coefficient of variation currently at 31%, summer rainfall there has in statistical terms become more reliable. Both sites are showing a significant reduction in autumn rainfall, after an apparently steady increase, the most striking difference being the decrease in variability over time. If some of these trends are genuine symptoms of the way our climate is changing, they would imply a reduced risk in future of autumn and winter floods. Extreme variability of summer rainfall may prove to be more of a challenge, and not just for those in the agricultural sector of the economy.

TABLE 8. Nettlecombe Court: Wettest (A) and driest (B) seasons and years (mm).

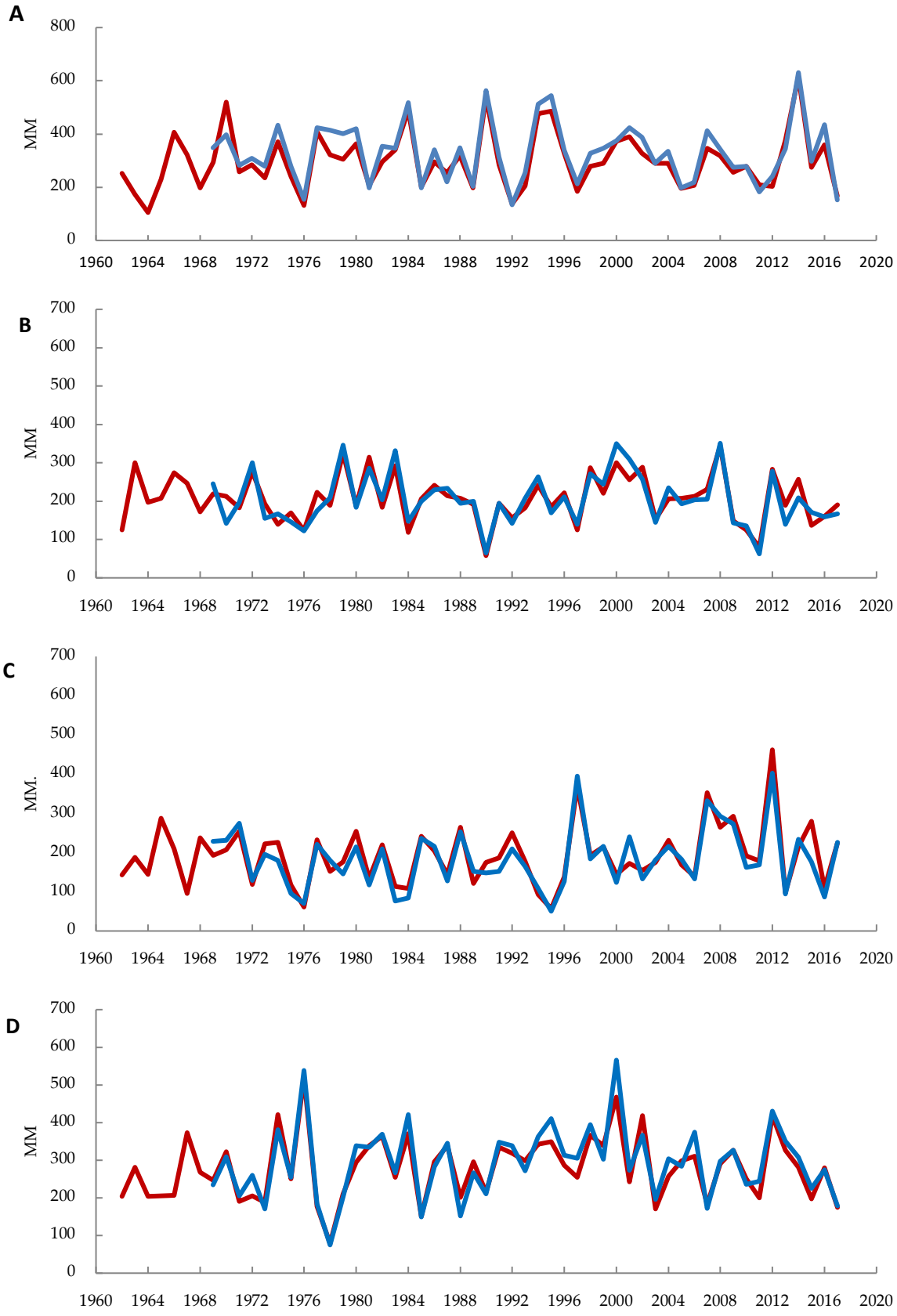
	A. Wettest									
	Winter		**Spring**		**Summer**		**Autumn**		**Year**	
1	630.8	*2014*	350.8	*2008*	402.6	*2012*	565.8	*2000*	1422.3	*2012*
2	562.6	*1990*	350.0	*2000*	394.8	*1997*	538.3	*1976*	1402.3	*2000*
3	543.3	*1995*	346.1	*1979*	331.7	*2007*	430.6	*2012*	1295.8	*2014*
4	517.0	*1984*	331.7	*1983*	292.0	*2008*	420.5	*1984*	1235.5	*2002*
5	513.0	*1994*	309.4	*2001*	275.0	*1971*	410.1	*1995*	1220.5	*1999*

	B. Driest									
	Winter		**Spring**		**Summer**		**Autumn**		**Year**	
1	133.9	*1992*	62.5	*2011*	50.4	*1995*	74.9	*1978*	690.4	*1973*
2	152.3	*2017*	65.5	*1990*	70.5	*1976*	149.0	*1985*	726.2	*1975*
3	154.8	*1976*	122.9	*1976*	75.9	*1983*	152.3	*1988*	739.1	*2010*
4	183.3	*2011*	139.5	*2013*	84.6	*1984*	170.4	*1973*	754.7	*2011*
5	196.9	*2005*	139.6	*1997*	87.0	*2016*	172.6	*2007*	804.7	*2003*

TABLE 9. Changes in seasonal distribution of rainfall (mm) over time.

A.	**Nettlecombe Court**											
	Winter			**Spring**			**Summer**			**Autumn**		
	Mean	Std. Dev.	Coeff.	Mean	Std. Dev.	Coeff.	Mean	Std. Dev.	Coeff.	Mean	Std. Dev.	Coeff.
1971 -2000	334	113	34%	209	67	32%	172	71	41%	303	106	35%
1981-2010	326	110	34%	215	67	31%	183	77	42%	308	87	28%
1991-2017	326	117	36%	206	69	33%	195	87	45%	313	84	27%
2001-2017	320	117	36%	198	71	36%	208	83	40%	285	72	25%
B.	**RNAS Yeovilton**											
	Winter			**Spring**			**Summer**			**Autumn**		
	Mean	Std. Dev.	Coeff.	Mean	Std. Dev.	Coeff.	Mean	Std. Dev.	Coeff.	Mean	Std. Dev.	Coeff.
1971 -2000	208	76	37%	153	51	33%	164	59	36%	198	80	40%
1981-2010	195	65	33%	148	41	27%	158	55	35%	206	63	31%
1991-2017	195	71	36%	147	42	29%	169	57	34%	213	59	28%
2001-2017	197	73	37%	144	45	31%	172	54	31%	197	58	29%

FIGURE 18. Comparison of seasonal rainfall totals at Nettlecombe (**blue**) and Wellington (**red**). (A) Winter (Dec, Jan, Feb); (B) Spring (Mar, Apr, May); (C) Summer (Jun, Jul, Aug); (D) Autumn (Sept, Oct, Nov).



Daily Rainfall

With frontal rainfall being the predominant form of precipitation across the whole region, it is no surprise that the several recording sites show very similar day-to-day patterns. In the period for which comparable data are available, the annual number of days with more than 0.1 mm of rain at Nettlecombe is 184, slightly higher than at Sampford Brett and Wellington, and slightly lower than at Cobhay Farm and Chipley. Splitting the entire Nettlecombe data series in two, we find an increase from 177 in the first half of the period to 190 in the second. The highest number was 222 days in 1994 and again in 2000, and the lowest was 147 days in 1995. Six of the eleven years on record with 200 or more such rain days have occurred in the present century.

For the Nettlecombe data series beginning in 1968, the mean daily rainfall amount is 5.5 mm, with a Standard Deviation of 0.7 mm. The highest value was 6.9 mm in 1997, and the lowest 3.8 mm in 2011 (+2.0 SD and -2.4 SD respectively). The figures show no trend over time, although there was nearly a decade around the turn of the century when the mean value was close to 6 mm. Associated with that was an obvious increase in the annual number of days with 10 mm or more rainfall, paralleled to some extent by days with 20 mm or more. More recently, the year-to-year variation has become noticeably greater, 2010 having only fifteen falls ≥ 10 mm, but 2012 and 2014 each having forty-five.

Regarding the frequency of occurrence of particularly very wet days, the author has ranked lists of falls ≥ 20 mm in the Wellington area, for each month of the year during the past forty years. Working from that data base, it has been possible to cross-reference with the other recording sites in the area, leading to some interesting conclusions. For the whole period under scrutiny, May has been the month least likely to have such an event, having in total only one-third of the number of occurrences as does October, the month most consistently likely to experience heavy falls of rain. With some 430 recorded instances of a daily fall ≥ 20 mm at Nettlecombe, one can detect significant variations over time. Figure 19 shows the annual totals of falls ≥ 20 mm for Nettlecombe Court since 1969 and for Wellington since 1987, with the years 1995, 2000, 2008 and 2012 standing out for their high scores, and 2011 boasting just the one such event.

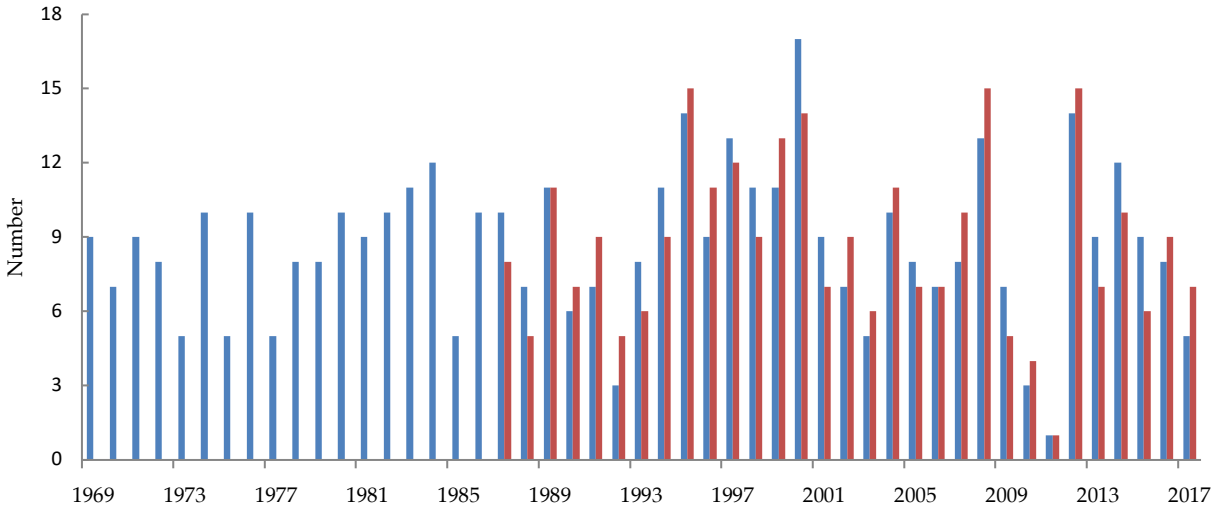


FIGURE 19. Annual Number of "Daily" Rainfall Events, 20 mm or more Nettlecombe (blue) & Wellington (red))

The frequency of occurrence of such wet days is shown to have increased erratically through the 1970s and 1980s, to reach a peak in the 1990s with an average of slightly above 10 per year. Since then, the frequency has dropped again, the first decade of the present century having an annual average of 7.7. For the period 2011 – 2017 inclusive the figure has increased to just over 8, which happens to be the mean value for the whole Nettlecombe data series. Analysis of a sample (n = 113) of daily falls ≥ 20 mm at Nettlecombe and/or Cobhay Farm up to the year 2000 showed that on roughly 75% of occasions the difference between rainfall amounts at the sites was less than 5 mm, with Nettlecombe showing an annual average of 8.5 falls against 7.2 at Cobhay and receiving significantly more falls in the 30 mm-plus category. Using the figure of 6.0 per year calculated for the 1960s from the Cobhay data, one can reasonably estimate a figure of about 7.3 for Nettlecombe during that decade. Comparing Nettlecombe and Wellington, for the thirty-year period ending in 2017, the total number of such falls is almost identical, and in one in five instances of heavy falls recorded at both Nettlecombe and Wellington the amount was greater at the latter site.

Extreme rainfall events

Within weeks of the start of daily rainfall observations at Nettlecombe, a fall of 71mm was recorded. On that same day, 10th July 1968, 77 mm was recorded at Cobhay and 80 mm at Sampford Brett, although none of these measurements bore comparison with the 175 mm recorded at Chew Stoke in north-east Somerset. With the zone of heaviest precipitation centred over the Mendip Hills, there was extensive flood damage especially in Cheddar, with much media coverage. Nettlecombe's weather diary for that date shows a gentle flow of air from the north-east, associated with a slow-moving thundery depression over the English Channel[12].

Little more than a year later, the area experienced an even heavier fall. July 28th 1969 saw prolonged thundery rain affect a zone from Plymouth to the East Riding of Yorkshire. In our study area, the precipitation began before dawn on a day totally lacking wind, and continued unabated for some twenty-eight hours giving totals well in excess of 100 mm. The "daily" fall for July 28th at Nettlecombe was 110 mm, and at Sampford Brett 101 mm. At Cobhay Farm the total was unknown, as the rain gauge was at one point found to be overflowing, but it was certainly in the order of 100 mm. This remains the largest rainfall event on record in the area, although the UKMO *Monthly Weather Report* for August 1970 notes a total of "nearly 98 mm" recorded at Timberscombe, some 11 km west-north-west of Nettlecombe and on the edge of Exmoor.

TABLE 10. Nettlecombe Court: Largest "daily" rainfall events (mm) in each month and years of occurrence.

Rank	Jan	Year	Feb	Year	Mar	Year	Apr	Year	May	Year	Jun	Year
1	38	1992	40	2002	39	1987	40	2012	43	2008	74	1997
2	37	1978	35	1994	35	2005	37	2004	35	1996	46	1971
3	35	1984	32	2014	35	2008	33	2000	33	1983	44	2009
4	35	1999	31	1997	34	1971	31	1984	29	2005	41	2004
5	33	1999	30	1974	31	1984	31	1991	28	1977	40	2005
6	32	1974	30	1990	30	1980	31	2001	28	2007	35	1972
7	31	1988	30	1991	29	1982	28	1987	28	2008	35	2006
8	30	1984	30	2016	29	1989	28	1994	28	2013	34	1980
9	30	1995	29	1978	28	1996	26	2000	27	1978	32	1986
10	30	2016	28	2009	27	1982	24	2000	25	2008	27	1973

Rank	Jul	Year	Aug	Year	Sep	Year	Oct	Year	Nov	Year	Dec	Year
1	110	1969	78	1970	72	1975	65	2000	46	2002	59	1979
2	71	1968	55	1997	71	1991	46	2002	45	2012	51	2000
3	57	1978	43	1976	63	2012	43	2006	42	1994	50	2013
4	39	2012	41	1986	47	1976	42	1997	38	1969	47	1985
5	38	2004	36	1969	45	1980	39	1976	38	2012	46	1985
6	34	2001	35	1986	42	1999	39	2014	36	1990	44	2004
7	29	2008	34	1977	41	1994	37	1976	34	1982	42	2003
8	28	1982	33	1988	38	1986	36	1980	34	2000	41	1981
9	27	2009	32	1973	37	1981	33	1979	33	1986	33	1981
10	27	2017	32	1997	36	1983	32	1989	32	2005	33	2003

Table 10 shows the ten largest recorded daily falls at Nettlecombe for each month of the year, and the years of occurrence. It is immediately apparent that the most extreme rainfall events have been in the warmer months of the year (June to September), when higher temperatures allow the atmosphere to contain larger volumes of water vapour to be precipitated when conditions are right. In five months, half the ranked major falls have occurred from the year 2000 onwards, although there has been only one in January and none in August. The observed tendency for winters to become less wet accounts for the January data, but with several recent Augusts having been relatively cool and cloudy, the recent lack of extreme rainfall events seems slightly illogical. In fact, lower temperatures may be linked to the observed reduction in the number of thunderstorms in late summer, when unusually large amounts of rain might be expected. Data for Wellington exhibit a very similar pattern.

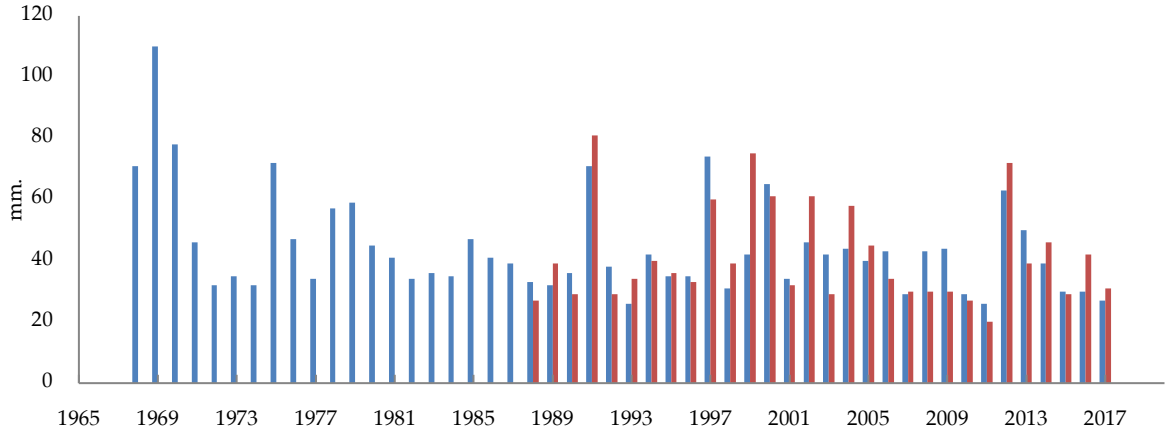


FIGURE 20. Annual heaviest "daily" rainfall event Nettlecombe (**blue**) & Wellington (**red**).

Figure 20 shows the heaviest daily falls each year for the two sites. Sampling by decades, one finds very little change in the mean heaviest fall of the year, it being consistently very close to 40 mm at both sites. Data analysis reveals that, regarding magnitude of falls, there is a closer match between Nettlecombe and Wellington, than between Nettlecombe and Sampford Brett. This village is a relatively near neighbour but has recorded 20% fewer instances of daily rainfall events ≥ 20 mm.

Another characteristic of major rainfall events in the area does not seem to have changed over time. Analysis of a sample of one hundred daily falls of 30 mm or more at Nettlecombe shows that 62% of such events are associated with winds from between south and west, the prevailing quarter. However, closer scrutiny reveals that in spring and summer the great majority of these, albeit infrequent, heavy falls occur with a wind from an easterly quarter. In some instances, they account for a disproportionately large percentage of the total annual rainfall, as in 1997 (16%). In no fewer than twenty-two of the forty-nine years of rainfall records at Nettlecombe the heaviest daily fall has occurred with a wind having an easterly component. Interestingly, these findings are broadly in line with conclusions reached by the author in his original paper on Nettlecombe's climate (Ratsey, 1973).

Minor spatial variations are detectable in the magnitude of these notable rainfall events with winds from different directions, as observed at Nettlecombe at 0900 GMT, and recorded in Metform 3100. Comparing the two main sites featured in this study, there is a rather weak statistical signal suggesting that with a southerly wind the rain shadow created by the Brendon Hills causes a relative reduction in the amount falling at Nettlecombe. There is a slightly stronger signal that with an easterly wind, rainfall is heavier there than in Wellington. Major rainfall events with winds from between west and north-west are least frequent at both sites but tend to be of significantly greater magnitude at Nettlecombe. Under such weather conditions (typically the cold sector of an Atlantic depression) the Exmoor massif creates a wide rain shadow across the lower-lying area to the south-east, which includes Wellington.

As well as the fluctuations from year to year, there have been some changes over time affecting the different seasons. Until the end of the 1980s, a fairly consistent 60% or so of these heavy daily falls occurred in autumn and winter. In the 1990s this rose to almost 75%, with a sharp drop in the number occurring in summer. However, the first decade of this century saw the lowest numbers for autumn and winter in the entire series, and the highest for spring and summer, which links to the seasonal changes in precipitation patterns in recent years already noted. From the Wellington data, the most noteworthy feature is the great increase since the mid-1990s in the number of heavy falls in April, May (especially), June and November, which is reflected to some extent by the Nettlecombe data shown in Table 10.

Droughts and Wet Spells

While the word "drought" has several meanings depending on its context, meteorologists customarily use the term to refer to a period without significant (if any) rainfall. In the UK, an "absolute drought" describes a period of fifteen or more days with no more than 0.2 mm of precipitation on any one day. Using that criterion, we find that the earlier daily records from Cobhay Farm show even a very dry year such as 1964 to include only one such period, from July 19th to August 5th. 1965 and 1966, both wet years, contained no periods of absolute drought, although in 1965 both February and October were remarkably dry. Lengthy dry spells then became more frequent, with 22 consecutive rainless days in June 1967, and near-drought conditions in January and July of that year, with the following two years each containing two spells of absolute drought of about 20 days' duration.

With rainfall records beginning at Nettlecombe in the summer of 1968, a very similar pattern can be identified. Both sites experienced what was, at the time, their longest rainless period starting on May 16th 1970, and lasting for 28

days at Cobhay and 31 days at Nettlecombe. Although there was a 24-day absolute drought in September/October 1972, and 20 consecutive days without rainfall in the summer of 1975, it was in 1976 that the records were set. Between mid-April and late August there were three separate periods of absolute drought, the chief one commencing on July 20th and lasting for 39 days.

Although four of the next five years each contained one period of drought, none was longer than 16 days. The next notable year was 1984, with two 32-day droughts starting respectively on April 12th and June7th. After that, no absolute drought longer than 21 days was recorded at Nettlecombe until the notable summer of 1995. In that year, starting on June 13th, there was a spell of 26 days without measurable rainfall, to be followed by a 23-day dry spell starting on July 30th. However, since the spring of 1997, with a 28-day drought, such prolonged rainless periods seem to have become less frequent. A few years had no absolute droughts, including some such as 2006 that had noteworthy spells of hot summer weather. In contrast, the memorably wet summer of 2007 was preceded and followed by two of the most prolonged absolute droughts of the 21st century so far, the one ending on September 23rd having lasted for 33 days[14]. In general, the typical duration of absolute droughts seems to now be in the range 15 – 18 days, with such spells appearing to be becoming more frequent in winter and spring. This is perhaps reflected in the changes in patterns of seasonal rainfall that have already been noted.

Regarding "wet spells", in the absence of a generally accepted definition for the purposes of statistical analysis, it was decided to adopt the "wet day" (*i.e.* having 1 mm or more of rainfall) as the threshold value. Initial studies then showed that unbroken sequences of more than ten such days were very scarce. Therefore, for the present purposes, a wet spell has been redefined as "a period of at least fifteen days, with no more than one day having less than 1 mm of rainfall". From the Cobhay Farm records, such spells can be identified in the winters of 1965, 1966 and 1967. Also, in 1967, an exceptionally wet May contained only four rain-free days, with an unbroken wet spell from May 12th to 30th. Comparing the Cobhay and Nettlecombe records, we find both sites had qualifying wet spells in January and November 1970, while at Nettlecombe the sixteen wet days culminating on January 31st 1971yielded a total of 184 mm of rain.

Following the drought of 1976, there was just one rainless day at Nettlecombe between September 21st and October 14th, the total precipitation for that period being 293 mm. There was a 15-day wet spell in November 1982 and a 20-day spell in the autumn of 1984, while the autumn and winter of 1987/88 contained three qualifying wet spells. Most winters in the early 1990s included a wet spell, notably one of twenty days in December 1993. In the second half of that decade, wet spells generally seemed to extend to no more than about twelve days, with just one 15-day spell in the autumn of 1998, but then three separate ones occurred between mid-October and Christmas 2000 – a period of memorable floods in many parts of the country. A total of 492 mm of rain was recorded at Nettlecombe during that period, and 420 mm at Wellington. (The Cobhay Farm recording site closed in November that year.)

Coming into the 21st century, and relying more heavily upon data for Wellington, the most notable feature has been the increased frequency of sustained wet weather at the "wrong" time of year. Although not containing wet spells that qualify under the criteria being applied in this study, months that stand out include June 2007 and 2012 (4 rain-free days), July 2008, 2009 and 2012, and August 2008 and 2012. Most noteworthy perhaps was the second half of April 2012, being a 15-day wet spell with almost 200 mm of rain in Wellington. There have been wet spells also in the seasons when they would be expected, as in January and November 2002, the latter being the first example of a calendar month with measurable rainfall at Nettlecombe on every day.

In recent years, there were significant autumn or winter wet spells in November 2010, October 2012 and December 2012. By far the most sustained period of wet weather was in the winter of 2013 – 2014. Referring to the Wellington data, in the eighty-one days between December 12th and March 3rd, there were just five without precipitation. Within that, there was rain every day from December 12th to January 10th, and on every day in February. The total precipitation of almost 634 mm in such a short period of time is unrivalled in the local records and equates to almost 65% of an average year's rainfall. At Nettlecombe, no rainfall record exists for December 2013 but in the light of very similar totals for January and February 2014 at both sites, that figure may be regarded as sufficiently representative for the area as a whole.

CLIMATE CHANGE

While there has been no particular emphasis placed on changes in the climate of the area in this study, it will be evident to the reader that a number of significant shifts have been noted, either in the text or as suggested by the data presented. From a perspective of the 21st Century to date, one can make the following summary statements:

- The mean annual temperature is now about 1°C higher than it was in the period 1961 – 1990, in line with changes observed at Malham Tarn (Burt & Horton, 2003) and arguably equating to a "migration" of two degrees of latitude southwards.
- While mean daily maxima are now at their highest recorded levels in all seasons, it is the great increase in mean daily minima in summer and autumn that is chiefly responsible for the difference observed.

- Mean diurnal temperatures appear to have increased for almost every day of the year. The graphs in Appendix B compare averages for the first thirty years and most recent thirty years of the Nettlecombe records, with only "high summer" showing relatively little change.
- Recent decades have seen a significant increase in the frequency of occurrence of unusually warm months, as illustrated in Figure 10.
- On average, summer arrives a week earlier and extends a week later than previously, while the mean date for the first air frost of autumn in the area is now eighteen days later than for the period 1961-1990.
- Data from the different sites suggest that the warming process has been more rapid at Wellington than at Nettlecombe, for reasons that are not clear.
- Lengthy spells of notably hot weather in summer, and also of notably cold weather in winter, are now less frequent in the area, but the present century has seen unprecedented spells of unseasonable warmth in autumn, winter and spring.
- A measurable increase in mean annual rainfall with each decade to the turn of the century seems to have paused, but year-to-year variability has increased. However, the wettest spring, summer, autumn and winter on record have all occurred from the year 2000 onwards, and the four wettest years, as shown in Table 8.
- Changes to seasonal patterns of rainfall have been more significant. In particular, summers have become wetter overall but more variable, while autumns have become drier and less variable, as suggested by Figure 18.
- The mean annual number of days with rain has increased slightly, with no significant trend apparent in the mean "daily" amount of rain. However, the present century has seen a disproportionately large number of notably heavy falls, especially in the period April – July, as shown in Table 10.

Notes

1. The author's early interest in climate change was increased by his reading of a paper titled *"Britain's Changing Climate"* (Lamb H.H, 1967) by the then Climate Research Officer at the Meteorological Office, presented to the Royal Geographical Society in December 1966. Although given in a context of a perceived rapid cooling of climate globally, and with an historical perspective, this has proved to have been remarkably prescient in warning of the possible environmental, social and economic impacts of future changes of climate.
2. Regular monitoring of temperatures at a large number of unofficial sites is now possible through the Weather Observations Website. Even allowing for the probable non-standard exposure of some thermometers or temperature sensors, there is a growing body of evidence for a lowland zone that experiences higher-than-expected daily maxima in summer. This would appear to extend from around Taunton to the Exeter area, including the towns of Wellington and Cullompton. The lack of historic weather records for this area makes it impossible to tell whether it is a recent development, or that it has always been thus.
3. For the region as a whole the spring of 2017 was the third warmest on record, and it was the fourth warmest year. Unfortunately, the significant breaks in the Nettlecombe data series in 2017 prevented the calculation of accurate monthly averages but cross-referencing with the data for Wellington gave seasonal values that were in line with regional ones.
4. July 2018 was the warmest since 1983, including only three days at Nettlecombe with maxima below 21°C, but with the small number of really hot days similarly occurring as scattered ones or twos throughout the month.
5. In 2018 the notorious "Beast from the East" gave an eight-day spell starting on February 23rd with a mean diurnal temperature of -1.5°C, with a record low maximum of -1.8°C on March 1st. The short-lived return of the "Beast" in mid-March resulted in a maximum of -1.1°C at Nettlecombe on March 17th, by far the latest date on record for a sub-zero maximum at the site.
6. The author clearly remembers that UKMO queried the report of an air minimum of -9.8°C at Nettlecombe in January 1972. The official opinion was that it was highly improbable at a site so near the coast.
7. According to the UKMO *Monthly Weather Report* for April 1980 it was a warmer-than-average month, and only in parts of Scotland were temperatures as low as -5°C recorded.
8. This is based on data for RNAS Yeovilton, the nearest lowland UKMO climate station that publishes sunshine records.
9. Experience has shown that for many plants this equates to a "killing frost", with temperatures at ground level likely to be a few degrees lower.
10. Reference to the monthly data reveals that it was the first and fourth quarters of 1973 that were notably dry, their combined rainfall total making up only 42% of the annual figure. No equivalent seasonal imbalance has been recorded there since.
11. It should be noted that in a low-rainfall area such as at Yeovilton, an extreme rainfall event can have a much greater proportional effect on the total than does the same magnitude of rainfall event at a rainier site. A case in point occurred in 2016, when a single thunderstorm resulted in June in that year being among the wettest ever at Yeovilton, while the western half of the county was unaffected. This would account for the upward kink in the Yeovilton curve in Figure 16.
12. The author recalls the occasion because, in the six years since starting his own rainfall records, he had measured no daily fall greater than 1.25 inches (32 mm), in any month.
13. In the 100 days ending on August 27th 1976 less than 24 mm of rain was recorded at Nettlecombe, 26 mm at Sampford Brett and 30 mm at Chipley. These figures suggest that the whole of the area in this study was similarly dry.
14. The summer of 2018 included a 44-day period ending on July 15th during which measurable rainfall occurred on just five days, amounting to 7.5 mm in Wellington. This was the most sustained dry spell to date in the present century, although technically-speaking not a period of drought.

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APPENDIX A.

Monthly Mean temperatures at selected stations, 1981 - 2010 (ºC) (UK Met Office data except Wellington).

	Minehead				
	Mean Max.	Mean Min.	Mean Diurnal	Diurnal Range	Air Frosts
Jan	8.6	3.6	6.1	5.0	4.8
Feb	9.0	3.2	6.1	5.8	5.3
Mar	11.0	4.8	7.9	6.2	1.9
Apr	13.2	5.8	9.5	7.4	0.8
May	16.3	8.7	12.5	7.6	0.1
Jun	19.1	11.3	15.2	7.8	0.0
Jul	21.0	13.4	17.2	7.6	0.0
Aug	20.8	13.6	17.2	7.2	0.0
Sep	18.6	11.9	15.3	6.7	0.0
Oct	15.0	9.1	12	5.9	0.2
Nov	11.7	6.3	9.0	5.4	1.8
Dec	9.1	4.1	6.6	5.0	5.2
Year	**14.5**	**8.0**	**11.2**	**6.5**	**20.1**

	Yeovilton				
	Mean Max.	Mean Min.	Mean Diurnal	Diurnal Range	Air Frosts
Jan	8.3	1.7	5.0	6.5	11.1
Feb	8.5	1.4	5.0	7.1	10.3
Mar	10.9	3.0	6.9	7.9	7.5
Apr	13.4	4.0	8.7	9.4	5.0
May	16.8	7.2	12.0	9.6	0.7
Jun	19.7	10.0	14.9	9.7	0.0
Jul	21.8	12.1	16.9	9.7	0.0
Aug	21.6	12.0	16.8	9.6	0.0
Sep	19.0	9.9	14.5	9.1	0.0
Oct	15.1	7.3	11.1	7.8	2.0
Nov	11.3	4.0	7.7	7.3	7.0
Dec	8.6	1.8	5.2	6.8	9.2
Year	**14.6**	**6.2**	**10.6**	**8.4**	**52.8**

	Nettlecombe				
	Mean Max.	Mean Min.	Mean Diurnal	Diurnal Range	Air Frosts
Jan	8.2	2.1	5.2	6.1	9.2
Feb	8.3	1.8	5.0	6.5	8.9
Mar	10.6	3.2	6.9	7.4	6.1
Apr	12.9	3.9	8.4	9.0	3.5
May	16.1	6.6	11.3	9.5	0.6
Jun	18.9	9.2	14.1	9.7	0.0
Jul	20.9	11.2	16.1	9.7	0.0
Aug	20.7	11.2	15.9	9.5	0.0
Sep	18.3	9.3	13.8	9.0	0.0
Oct	14.5	7.1	10.8	7.4	1.5
Nov	11.1	4.4	7.8	6.7	4.9
Dec	8.6	2.2	5.4	6.2	8.9
Year	**14.1**	**6.0**	**10.1**	**8.1**	**43.6**

	Wellington				
	Mean Max.	Mean Min.	Mean Diurnal	Diurnal Range	Air Frosts
Jan	7.3	1.8	4.6	5.5	9.1
Feb	7.8	1.5	4.7	6.3	8.8
Mar	10.9	3.1	7.0	7.8	6.5
Apr	13.7	3.6	8.7	10.1	4.9
May	17.5	6.5	12.0	11.0	0.8
Jun	20.6	9.5	15.0	11.1	0.0
Jul	22.4	11.4	16.9	11.0	0.0
Aug	21.8	11.2	16.5	10.6	0.0
Sep	18.7	9.2	13.9	9.5	0.0
Oct	14.0	6.7	10.4	7.3	2.0
Nov	10.0	4.2	7.1	5.8	6.3
Dec	7.3	2.0	4.7	5.3	9.0
Year	**14.3**	**5.9**	**10.1**	**8.4**	**47.4**

APPENDIX B.

Nettlecombe Court: Changes in mean diurnal temperature over time. (A) Nettlecombe Court- diurnal mean temperatures Jan - June: 1969 - 1998 (green) and 1988 - 2016 (red). (B) diurnal mean temperatures July - Dec: 1969 - 1998 (green) and 1988 - 2016 (red).