Chapter 5
A Reconstruction of Medieval April–July Temperatures for East Anglia

A reconstruction of late medieval temperatures representative of the East Anglian region has been demonstrated by Pribyl et al. (2012). The medieval harvest date series used in the reconstruction has been discussed in Chaps. 2 and 3; those data were calibrated with the harvest dates 1768–1816 from Langham alongside the Central England Temperature series (CET).[1] In this chapter, a summary of the methods for the temperature reconstruction is provided. Since the initial reconstruction of the medieval temperature series, additional data have been found which result in a more complete series. Hence an updated temperature reconstruction is presented in this chapter.

5.1 Reconstruction Methodology

The temperature reconstruction follows the widely-used calibration-verification approach.[2] For this purpose the medieval data are expressed as year days from 1 January, and the values are adjusted from the Julian to the Gregorian calendar. Over the period 1256–1431 the number of harvest dates per year varies considerably, after c.1290 it is more stable (Fig. 3.5), and in total 645 harvest dates are available for late medieval East Anglia. These harvest dates come from 50 manors and each series of medieval dates contains a substantial number of missing values; some manors only yield very few data (Table 5.1). Hence the medieval harvest information has to be formed into a composite harvest date series for the whole of East Anglia by amalgamating the manors in regional groups that share broadly similar environmental conditions (climatic factors, soil conditions, altitude) (Fig. 5.1 and Table 5.1). For the twelve distinct regions the minimum value per year of each region was used (i.e. the earliest harvest date); substituting the minimum value with

[1] Manley, The mean temperature of central England, 1698–1952, 242–261, and idem, Central England temperatures: monthly means 1659–1973.

[2] Brázdil et al., European climate of the past 500 years. New challenges, 15–18.

K. Pribyl, *Farming, Famine and Plague*, DOI 10.1007/978-3-319-55953-7_5

Table 5.1 Regional groupings of the medieval manors

Region	Latitude	Longitude	Region	Latitude	Longitude
Northwest			**Taverham**		
Gnatingdon	52°53′	0°34′	Attlebridge	52°42′	1°08′
Heacham	52°54′	0°30′	Bawburgh	52°38′	1°10′
Hunstanton	52°56′	0°29′	Taverham	52°41′	1°12′
Ringstead	52°55′	0°32′			
Sedgeford	52°53′	0°33′	**Plumstead**		
Thornham	52°57′	0°34′	Plumstead	52°38′	1°24′
			South Walsham	52°39′	1°29′
Cromer Ridge					
Hindolveston	52°49′	1°00′	**Norwich**		
Hindringham	52°52′	0°56′	Arminghall	52°35′	1°18′
			Catton	52°38′	1°17′
Northeast			Costessy	52°39′	1°12′
Calthorpe	52°51′	1°13′	Cringleford	52°36′	1°14′
Hevingham	52°45′	1°15′	Eaton	52°37	1°15′
Little Hautbois	52°44′	1°19′	Heigham	52°38′	1°16′
North Walsham	52°49′	1°23′	Lakenham	52°37′	1°17′
Scottow	52°46′	1°22′	Monks′ Grange	52°38′	1°19′
Witton	52°49′	1°28′	Trowse Newton	52°35′	1°19′
Worstead	52°46′	1°24′			
			Southwest		
North Elmham			Fincham	52°37′	0°29′
Gateley	52°46′	0°54′	Gr. Cressingham	52°34′	0°43′
Kempstone	52°42′	0°47′	Hardingham	52°36′	1°01′
North Elmham	52°44′	0°56′			
			Southeast		
Norfolk Broads			Aldeby	52°28′	1°36′
Hemsby	52°41′	1°41′	Hardley	52°33′	1°30′
Martham	52°42′	1°37′	Shotesham	52°31′	1°18′
Ormesby	52°40	1°41′			
Scratby	52°40′	1°42′	**Suffolk**		
			Akenham	52°06′	1°07′
Flegg			Denham	52°18′	1°13′
Ashby	52°41′	1°34′	Henley	52°07′	1°08′
Flegg	52°40′	1°36′	Hinderclay	52°21′	0°58′
Ludham	52°42′	1°31′	Redgrave	52°21′	1°00′

The allocation of manors to a regional group is based on geographical proximity and mean values in grain harvest date (where available). Adapted from Pribyl et al. (2012)

the mean value of the dates results only in minor differences. Linked to the different environmental conditions the average of the individual regional series varies across East Anglia, e.g. the group of manors around Norwich tended towards early harvests, the group of harvest dates from Cromer Ridge was normally the latest.

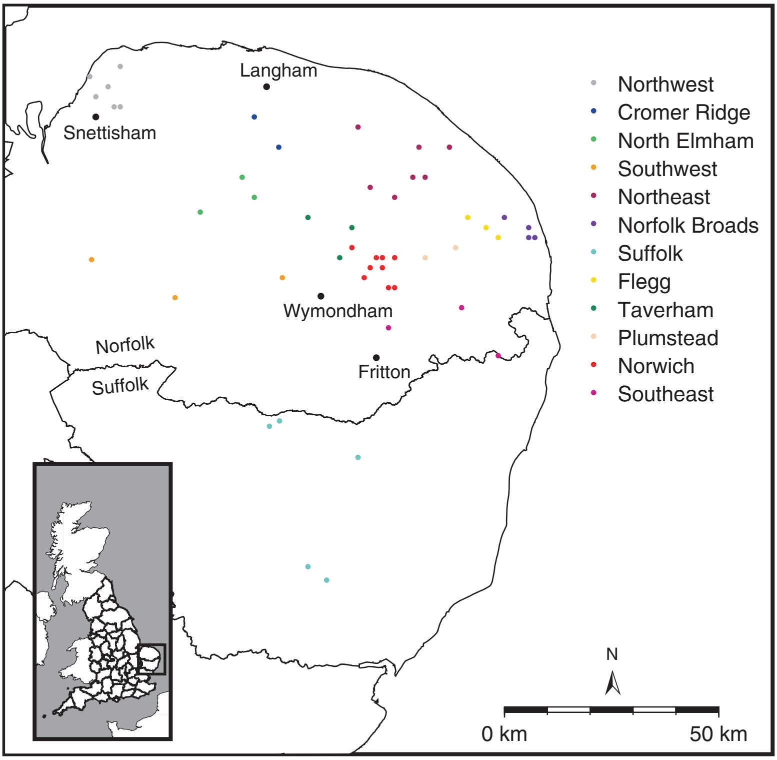

Fig. 5.1 Harvest date series: medieval regional groups and the modern comparison data from Langham. Also shown are the locations of the other farms (Fritton, Snettisham and Wymondham) providing eighteenth and early nineteenth-century harvest dates. For the composition of the medieval regional groups and the coordinates of the individual manors, see Table 5.1. (Adapted from Pribyl et al. 2012)

The most complete and longest series of harvest dates comes from the Northwest region which includes the manors of Sedgeford and Gnatingdon. To achieve a homogenous composite series for East Anglia, the other regional series were regressed to the level of the Northwest group, and the missing values in the Northwest series were filled in with regressed data of the other regional groups. The information was chosen in a hierarchical manner based on the strength of the relationships (r^2 value of each group) relative to the Northwest group. The resulting East Anglian composite series provides harvest dates for 147 years between 1256 and 1431. Forming the composite series by regressing the data to a specific regional group is preferable to a composite series consisting simply of the mean values of the regional data available per year, since the latter method would suppress the interannual variability. However, apart from extremes, it was the interannual variability that was most keenly felt by the medieval people and that impacted directly on agricultural success; hence this time series component is essential for the historian.

The medieval Northwest group and the home of the modern comparison series, Langham, are both close to the North Sea and are separated by a distance of about

Table 5.2 Medieval East Anglian composite series and the modern comparison series (Langham): statistical characteristics

	East Anglian composite series 1256–1431	Langham 1768–1816	Langham 1818–1867
Mean	226.82	228.45	220.17
SD	7.10	7.52	7.60
Min	204	215	206
Max	247	250	238
N	147	44	42

Adapted from Pribyl et al. (2012)

25 km. The medieval Cromer Ridge group is geographically closer to the modern comparison series, however, Cromer Ridge has merely half of the number of harvest dates of the Northwest group, making a regression to the level of Cromer Ridge statistically more risky. Langham also shares actually more geo-physical properties with the Northwest group than with Cromer Ridge. The Northwest region and the village of Langham are surrounded by similar, generally well draining soils, whereas Hindringham and Hindolveston of the Cromer Ridge group are situated on mainly loamy or clayey soils, which are subject to slight seasonal waterlogging.[3] The Cromer Ridge group is not only more vulnerable to high rainfall levels, but also lies on slightly higher ground than Langham and the Northwest group.[4] As a result the growing season is shorter for the Cromer Ridge group (<260 days), than for Langham and the Northwest group (>270 days).[5] Concerning mean values the early part of the Langham series 1768–1816 (mean value of year days 228.45) and the region Cromer Ridge (mean value of year days 228.93) are actually almost identical, whereas the value for the medieval Northwest region (mean value of year days 226.55) is c. two days lower than at Langham (Table 5.2). This tendency of the modern Langham harvest data towards slightly later harvests than in the medieval Northwest group can indeed be explained by the coinciding of the Langham series with a period known to have been cold, particularly around 1800, probably partly due to the Dalton Minimum, and also by the modern comparison series catching the disastrous impact of the eruption of Mount Tambora (1815) in the very cold summer

[3] Soils of England and Wales: Sheet 4 Eastern England, the fields of Sedgeford-Gnatingdon are dominated by shallow well drained calcareous sandy and coarse loamy soils over chalk or chalk rubble belonging to the soil association of Newmarket 2, and to a small extent include deep well drained coarse loamy, coarse loamy over clayey and sandy soils (Barrow). At Langham similar soils are involved (Newmarket 1 and 2, Barrow). The soils at Hindringham and Hindolveston are mainly deep loamy with slowly permeable sub-soils prone to slight seasonal waterlogging (Burlingham 1 and 3), or slowly permeable seasonally waterlogged fine loamy over clayey soils (Beccles 1 and 2).

[4] According to the Ordnance Survey: 132 North West Norfolk and 133 North East Norfolk, Langham and fields are at 30-40 m, the Northwest region at 30-50 m, Hindringham at 50-80 m and Hindolveston at 50-70 m.

[5] MAFF, Sheet 125 Fakenham, 4–5 and MAFF, Sheet 124 King's Lynn, 4.

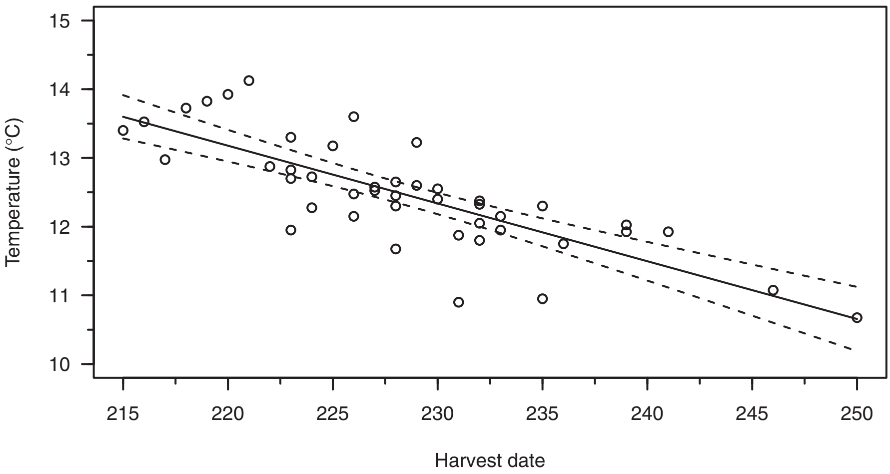

Fig. 5.2 Scatterplot of the Langham 1768–1816 harvest dates and CET temperatures. Plotted are the mean April–July temperature derived from the CET series, the linear regression line and the 95% confidence interval. (Taken from Pribyl et al. 2012)

half year 1816. For the aforesaid reasons it is preferable to regress to the level of the Northwest region.

As shown in Table 5.2 the statistical properties of the medieval East Anglian composite series regressed to the Northwest group are close to those of the Langham harvest date series 1768–1816. Consequently the correlation of this earlier part of the Langham harvest date series (n = 44) with the CET series can form the basis of the medieval temperature reconstruction.

The main factor determining the harvest date at Langham is the mean temperature during the period April to July, which is responsible for 62% of the variance in the harvest dates (r = −0.79, Fig. 5.2). However, correlations remain high, when March and/or August temperatures are also included in the analysis. March temperature is connected to the onset of the growing season. The cold northerly or easterly winds which are frequent in Norfolk, can delay plant growth in early spring.[6] It is indeed the temperature during the grain growing season that displays a strong linear relationship with the grain harvest date. A substantial percentage of the unexplained variance is probably connected to the sowing time and the rainfall during the growing season.

The reconstruction of April to July mean temperatures was achieved by using the harvest dates from the medieval composite series and the regression coefficients established over the period 1768–1816. As the break in the Langham series only affects the mean value, the data over the years 1818–1867 were used to verify the prediction of temperatures (Fig. 5.3). Over that period the correlation between recorded and reconstructed temperatures stood at r = 0.86 (r^2 = 0.73).

[6] This problem was already described in 1796 by Kent, General view of the agriculture of the county of Norfolk, 10. It is a Norfolk-wide phenomenon, see for example MAFF, Sheet 124 King's Lynn, 4 or MAFF, Sheet 126 Norwich, 5.

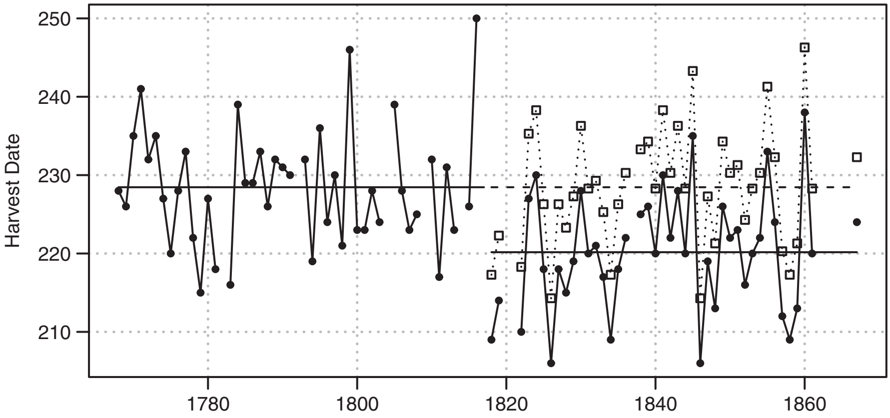

Fig. 5.3 Langham harvest dates with adjustment of the later part of the series. The *dotted line* represents the adjusted mean value of the later part of the series (1818–1867) so it equals that of the earlier part (1768–1816). The *horizontal lines* indicate the means of the early and late parts. (Taken from Pribyl et al. 2012)

5.2 Reconstructed Medieval April–July Mean Temperatures

The reconstructed April–July mean temperatures (Fig. 5.4) show a long term trend of decline over the period 1256–1431. Overall the initial version of the temperature reconstruction as presented in Pribyl et al. (2012) and the new version are very similar despite adding about 30 new harvest dates. Most of these harvest dates fall into years for which data already existed, they either confirm these data or belong to regional groups such as 'Suffolk' which due to its distance to the Northwest region and its greater geographical scope, can only supply the harvest date for the reconstruction, if no date is available from any other region. Five previous gap years could be filled in this revised reconstruction: 1269, 1280, 1307, 1330 and 1351.

Before 1335 temperatures above 13 °C were much more common than in the later decades of the reconstructed period (Fig. 5.4, Appendix 4). Until c.1315 springs and early summers were rarely colder than 12 °C. The hottest spring-summer in late medieval England, that of 1361 (14.5 ± 1.0 °C), was an outlier during the cooler decades 1350–1431. This value appears exceptional when compared to the more than 350 years of modern instrumental data (Fig. 5.5). However, it extends beyond the range for which the linear regression relationship was established in the 1768–1816 period. The lowest growing season temperature was reached in 1428. The coldest year of the reconstruction comes towards the end of the study period, and indeed the frequency of growing seasons colder than 12 °C also increased over time; they were common after c.1360. During the reconstruction period the average April–July temperatures decreased from about 13 °C at the beginning to 12.4 °C at the end. Within the context of this long-term trend, April–

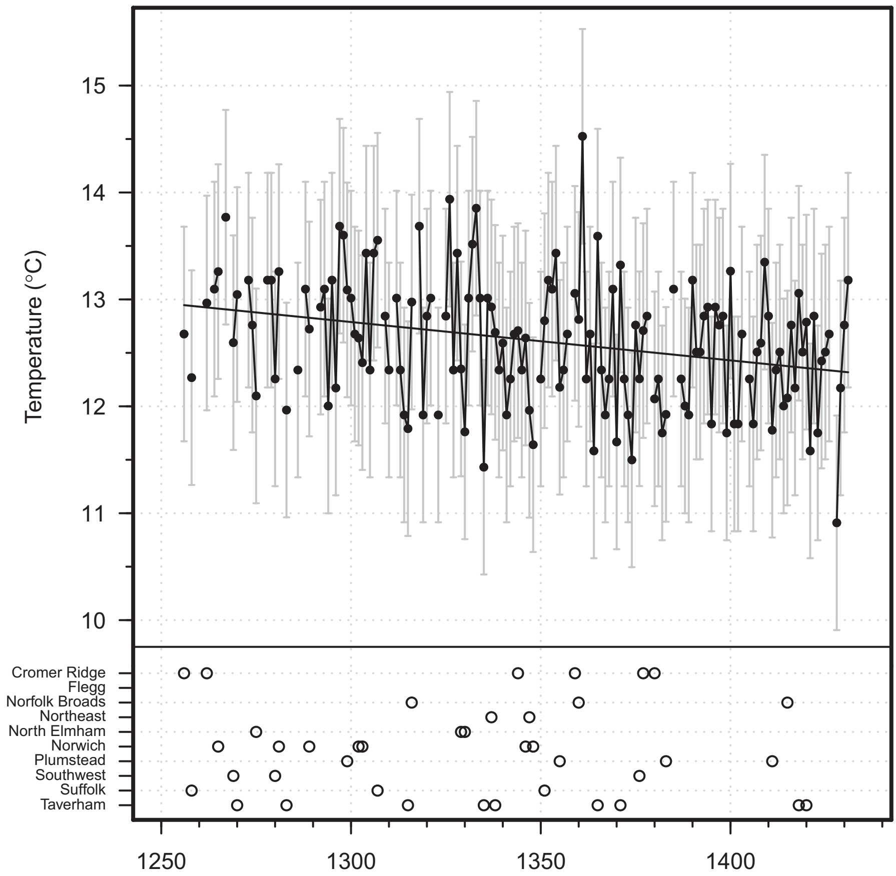

Fig. 5.4 The reconstructed April–July mean temperatures. The uncertainty range for each reconstructed temperature (the grey error bars) represent ±2S.E. The *circles* from the lower panel indicate values that have been filled with data from other regional groups regressed to the Northwest series. (Adapted from Pribyl et al. 2012)

July mean temperatures considerably higher than the preceding or following years occurred in 1267, 1297, 1298, 1307, 1318, 1326, 1332, 1333, 1361, 1365, 1371, 1385, 1390, 1400, 1409 and 1431. Grain growing seasons characterized by very low temperatures fell to the years 1275, 1283, 1294, 1314, 1315, 1319, 1323, 1330, 1335, 1348, 1364, 1370, 1374, 1421 and 1428. However, the decrease of the April–July mean temperatures is not steady over the study period. In the years c.1300–1310, 1326–1334, in the 1350s, the 1390s and the late 1410s local highs with respect to temperature are perceptible; whereas lows occurred in mid-1290s, c.1313–1323, in the late 1340s, from the mid-1360s to the mid-1370s, in the 1380s, the first decade of the fifteenth century and the early 1420s.

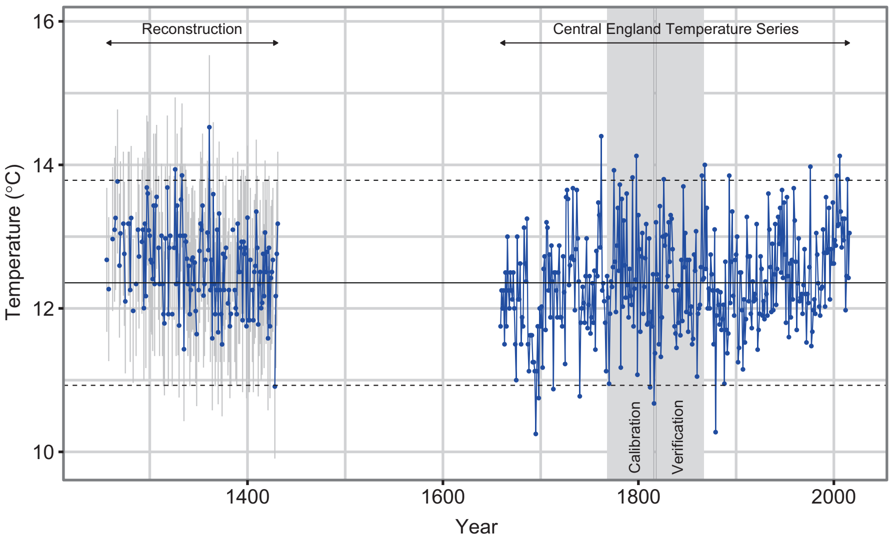

Fig. 5.5 The reconstructed temperatures in relation to the instrumental CET data. As with Fig. 5.4 the error bars represent ±2S.E. Displayed are the mean (*horizontal line*) and the ±2 standard deviations (*horizontal dashed lines*) of the instrumental data (1659–2016). Calibration (1768–1816) and verification (1817–1867) periods are also indicated. (Adapted from Pribyl et al. 2012)

The interannual variability was also subject to changes. Until 1290 it was low, the majority of the growing seasons were warm with temperatures between 13 °C and 13.5 °C. Due to this low data density few data come in consecutive years, a conclusive analysis of interannual variability before 1290 is therefore not possible. Periods of low interannual variability returned between the mid-1330s and the late 1340s, in the second half of the 1350s, from the mid-1370s to the early 1380s, throughout most of the 1390s, and in the 1410s. Shifts of up to 1 °C, in the medium range of the interannual variability, fell to c.1290–1315, c.1405–1411 and the early 1420s. Remarkably high levels of interannual variability mark then the years 1315–1335 and 1360–1375; the year 1428 interrupts the comparatively calm time of the second half of the 1420s and the early 1430s; in those times changes in growing season temperatures of 1.5 °C or more are possible. Due to the grain crops being annual plants, that means their growing speed was not influenced by preceding years, and the grain harvest date being closely linked to the phenological phase of the grain ripening, the interannual variability in the growing season temperatures is captured very well in the grain harvest data.

When comparing the reconstructed medieval April–July mean temperatures with the instrumental temperature observations of the CET series 1659–2016, the mild conditions of the Medieval Climate Anomaly, and the transition towards lower temperatures in the mid-fifteenth century in association with the onset of the Little Ice Age are clearly visible (Fig. 5.5). The rate of interannual variability in the Late Middle Ages was comparable to the conditions in the instrumental measurements.

5.3 Comparison with Other Documentary Reconstructions

The medieval reconstruction provides the earliest annually-resolved temperature series for the British Isles. In this section the reconstruction is compared against two temperature indices based on documentary information: the monthly indices by Ogilvie and Farmer for England 1200–1432[7] and the seasonal indices by van Engelen, Buisman and Ijnsen for the Low Countries 751–2000.[8] Neither series included the evidence about the East Anglian grain harvest dates and they therefore offer a useful independent comparison.

The Ogilvie and Farmer indices can be considered an extension of Lamb's indices.[9] The indices were made on a monthly level; unreliable information was removed and new weather information included. The indices cover the spectrum from −3 (for temperature: very cold, for precipitation: very dry) to 3 (very warm, respectively very wet). Unfortunately due to the nature of the medieval documentary data, many gaps remain. Medieval narrative sources, such as chronicles, and the direct references to weather they supply, focus on extreme events. Normal conditions were generally not recorded, so that it remains unclear if gaps in the available data represent normal conditions or if references to more extreme weather have simply not survived the centuries. The grain harvest date series does not suffer from this problem, although gaps also occur. With regard to the indices, especially those on a monthly level, the gaps lead to difficulties when the creation of supra-monthly or seasonal indices based on them is attempted. Hence, the available information in spring and summer temperature is too scarce in the Ogilvie and Farmer indices, so that a useful quantitative comparison with the reconstructed April–July mean temperatures is not possible.

The work of van Engelen et al. for the Low Countries provides a more complete set of temperature indices based on documentary sources for this period. They cover the summer (May–September) and winter season (November–March). Between 1256 and 1431 information is available for 158 summers. It ranges from 1 or I (extremely cool respectively 'obviously cool') to 9 or III (extremely warm respectively 'obviously warm'). The data from the Low Countries are dense, they are also geographically close enough to East Anglia to allow a meaningful comparison. Even though the time of the year represented in the summer index from the Low Countries is not identical with April to July, the Spearman rank correlation between the two datasets stands at rho = 0.47. Summers that are identified as very warm in both the reconstructed East Anglian growing season temperatures and the summer season index from the Low Countries are 1267, 1297, 1304, 1326, 1333, 1352, 1361, 1371, 1385, 1390 and 1400; summers identified as very cold are 1275, 1283, 1294, 1314, 1315, 1330, 1335, 1406 and 1428 (Fig. 5.6a).

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7 Ogilvie, Farmer, Documenting the medieval climate, 124–128. The indices set by Ogilvie and Farmer for temperature between 1256 and 1431 are sparse and mostly relate to winter.

8 van Engelen et al., A millennium of weather, winds and water in the Low Countries.

9 Lamb, Climate. Past, present and future, vol. 2.

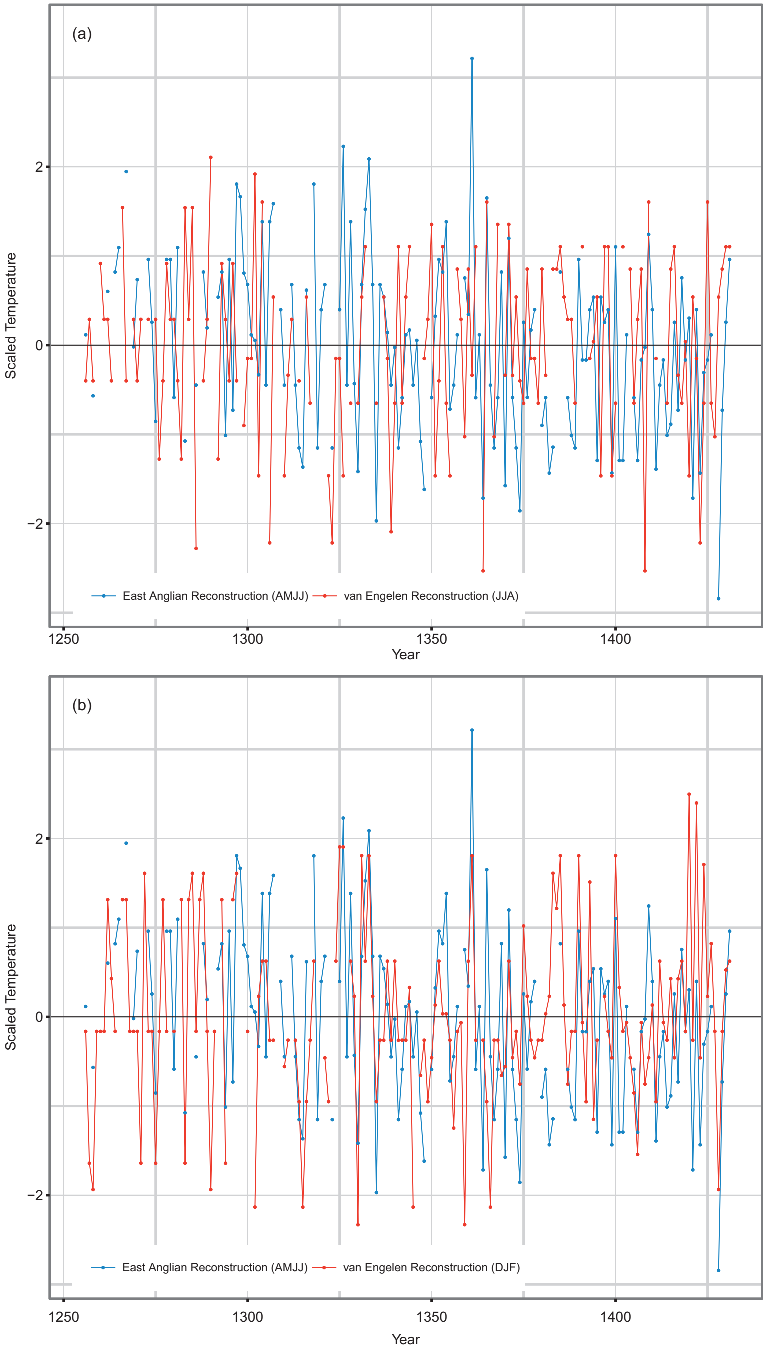

Fig. 5.6 A comparison of the van Engelen temperature series for the Low Countries and the reconstructed East Anglian temperature series for April–July. (**a**) Low Countries June–August and (**b**) Low Countries December–February. Data are presented in normalized units. The van Engelen indices covers May–September and November–March, the temperatures series, however, covers June–August and December–February. (Adapted from Pribyl et al. 2012)

In the light of the context provided by the van Engelen et al. index it becomes apparent that before c.1330 summers classified as very cold in the Low Countries index are poorly covered by the East Anglian data. This includes the years 1290 and 1322. These are categorized as very wet in the precipitation index for England by Ogilvie and Farmer, hence the cold weather most likely affected not only the continent but also the southern and eastern parts of the British Isles. The summer half years 1294 and 1330 are marked by very adverse weather in the Low Countries index, Ogilvie and Farmer note high rainfall levels again, and merely one East Anglian datum is available for each year confirming the very cold conditions. The time of the Great Famine 1315–1317 is also badly represented in the East Anglian series. Very few data are available for 1315 and 1316 and none for 1317. This lacuna in the East Anglian information during these periods of crisis is rooted in the low supply of manorial accounts available for years of bad weather and subsistence crises in East Anglia. Particularly the normally very reliable accounts for the prior's manors of Norwich Cathedral Priory are missing.

On a decadal level the datasets display broadly similar albeit offset trends before 1325 and between c.1360 and the mid-1370s (Fig. 5.6a). From 1325 to the late 1350s and also 1395–1420 the conditions in East Anglia and the Low Countries match closely. The trends diverge considerably in the 1380s and after 1420, but in the 1380s the East Anglian data density is too low to allow a meaningful comparison. Whereas the long-term trend in the data from East Anglia shows increasingly cool conditions over the study period, this development is not mirrored in the Low Countries.

In two periods the datasets diverge, even though data density is high. This is the case to a moderate degree between the late 1350s to c.1370, and to a higher degree after 1420. The datasets from East Anglia and the Low Countries do not represent the same period of the year, but overlap only between May and July, hence the cause for the break-up might lie outside these months. The months August and September are not included in the grain growing season, hence the focus here lies on April and potentially March, which are not covered by the summer index from the Low Countries. A winter season index, however, was also compiled; it is valid for November to March. During the study period 136 values are available in the winter index, and there are indeed occasions when the East Anglian data display a stronger connection to the winter instead of the summer conditions in the Low Countries (Fig. 5.6). The warm East Anglian growing seasons of 1278, 1316, 1365 and 1409 (Fig. 5.6b) are not mirrored in the summer index of the Low Countries, but did follow on from mild winters. For cold conditions in East Anglia a similar constellation involving preceding hard winters occurs in 1364, 1367, 1399 and 1423. An average East Anglian growing season is associated with a cold summer across the North Sea following on from a mild winter in 1302, and in 1420 and 1424 the situation was reversed. This connection between the winter index in the Low Countries and the East Anglian growing season mean temperature is due to the role of the length of winter. The onset of the growing season in March and April can be held up by cold conditions in early spring, from this interference follows a delayed harvest. Mild winters and early springs result in an early start of the growing season. Independent documentary evidence from England exists for the long winter 1363–1364 which was extremely hard and lasted well into March,[10] and for the winters 1422–1423 (Sect. 8.4) and 1423–1424.[11]

East Anglian data showing warmer conditions in the 1360s than those prevailing in the Low Countries are possibly related to a sequence of mild winters (except 1363–1364) that conceivably resulted from a predominance of westerly conditions across northwest Europe. At least during the later parts of the decade mild winters also prevailed in Central Europe.[12] Abundant precipitation in the summers[13] and partly also in the winters[14] add substance to this hypothesis. An early start of the growing season would have led to an earlier harvest, even though the summers were merely average. In addition, in 1369 the weather was marked at least by phases of warmer and drier weather previous to harvest time, but during the harvest it turned, and rain dominated the last part of the summer, influencing the summer index for the Low Countries but not the April–July temperature reconstruction (Sects. 6.3 and 8.4).

High spring-summer mean temperatures in East Anglia in connection with early onsets of the growing season and mild winters are distributed over the whole study period. Low temperatures in the East Anglian series without an adequate reflection in the Low Countries, but connected to severe winter conditions, however, only occur after c.1350 and cluster in the 1420s. In the Low Countries around 1420 summers were getting warmer and winters were cooling. This suggests that the long winters 1422–1423 and 1423–1424 were only extreme, but not atypical for the 1420s. Norfolk is particularly vulnerable to cold springs, because the northerly and easterly winds affect the county greatly, especially the land on the north coast and the manors of the Northwest group,[15] which supply the majority of the harvest dates for that decade. The high summer temperatures could not compensate for the delay of the growing season, thus the cool early springs noticeably cooled the reconstructed April–July mean temperatures. A shift in seasonality, that means a delay of the onset of the growing season as in the 1420s, was typical for the Little Ice Age and may be connected to the cooler conditions that have been associated with the Spörer Minimum.

The cause of the divergence of the data from East Anglia and the Low Countries in the 1380s cannot be determined; the growing season in East Anglia appears as much cooler than the summers in the Low Countries, particularly around 1380. In the Low Countries the winters were mild, although the central European winters are

[10] Ogilvie, Farmer, Documenting the medieval climate, 127.

[11] Titow, Le climat à travers les rôles de comptabilité, 338. Most references for the winter 1423–1424 are to rainfall of long continuation and subsequent flooding, so the winter was very wet. Overton in Hampshire, however, mentions tempests of snow and rain which continued for a long time, so the winter temperatures were probably below average.

[12] Pfister et al., Winter severity in Europe, 104.

[13] Ogilvie, Farmer, Documenting the medieval climate, 127, see Sects. 6.3, 8.4 and Fig. 7.5.

[14] Ogilvie, Farmer, Documenting the medieval climate, 127.

[15] MAFF, Sheet 124 King's Lynn, 4.

classified mostly as average or cold.[16] Documentary evidence from England for late springs survives only for 1388,[17] however, mostly information about long winters and delayed growing seasons comes from manorial accounts, and few of them are available for that period. Possibly in some severely hot and dry summers the vegetation development was hindered by drought, and drought was a feature of the summers in the mid-1380s in England (Sect. 8.3).[18]

5.4 Comparison with William Merle's Weather Diary 1337–1344

From 1337 to 1344 information on weather is available that is more continuous and detailed than the narrative or administrative sources: the 'Consideraciones temperiei pro 7 annis' by William Merle, one of Europe's oldest weather journals.[19] This long and detailed record of weather was most likely connected to Merle's work on predicting the weather.[20] Merle was the rector of Driby in northern Lincolnshire from 1331 onwards and probably a fellow at Merton College in Oxford after 1335; he died in 1347.[21] Merle's weather observations were partly made at Oxford and partly in Lindsey, northern Lincolnshire. He regularly recorded the weather, first weekly and after November 1339 almost daily. He noted all weather, not only extremes, as is generally an inherent problem of narrative sources. Towards the end of the journal Merle also tried to establish the spatial coverage of some weather events.

The weather diary offers parallel data to the East Anglian temperature series for the seven summer half years 1337–1343, a phase in which in the reconstruction as well as in the summer indices by van Engelen et al. for the Low Countries (2001) saw mostly average conditions and an extraordinary low interannual variability: the English reconstructed temperatures varied only on the scale of 1 °C (Fig. 5.7). Extreme events in the summer seasons of this period are also absent in Britton's weather compilation.[22] Nonetheless a year-to-year comparison between the Merle data and the reconstructed temperatures can prove instructive. A general

[16] Pfister et al., Winter severity in Europe, 104.

[17] Ogilvie, Farmer, Documenting the medieval climate, 127–128.

[18] Pfister, Variations in the spring-summer climate, 69.

[19] The oldest weather journal is also from England and covers the period of August 1269 to February 1270, Long, The oldest European weather diary?, 233–234. The references were written in the margin of an astronomical calendar for 1269 and might have been recorded by Roger Bacon. Another English weather diary, again in the form of notes taken on the margin of an astronomical calendar, survives for October to December 1439, Mortimer, William Merle's weather diary, 42.

[20] Meaden, Merle's weather diary and its motivation, 211, Mortimer, William Merle's weather diary, 42–43.

[21] Mortimer, William Merle's weather diary, 42–43. Driby is in the Lindsey district and within five miles of the northeast coast.

[22] Britton, Meteorological chronology, 138–140.

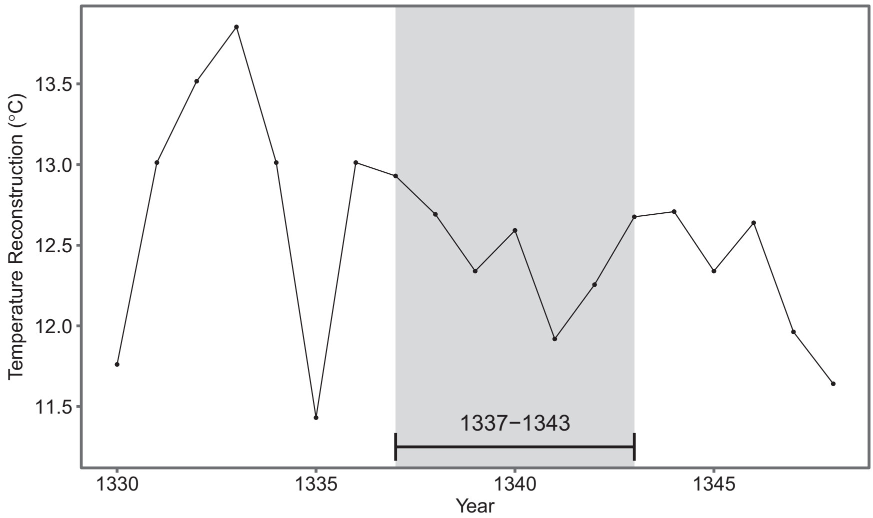

Fig. 5.7 Reconstructed April–July mean temperatures in East Anglia 1331–1348. The period within the *vertical lines* indicates the period covered by William Merle's weather diary 1337–1343

convergence between Merle's observations and data from manorial accounts from southern England and the London area has been demonstrated before.[23]

The two warmest reconstructed growing seasons overlapping with the Merle data are 1337 and 1338, though in the context of the whole series 1256–1431 these years are not extreme, but only somewhat above the long term average. In 1337 (see also Sect. 8.1) Merle describes April and May as moderately warm. Whereas April was wet, May was mostly dry and the dry weather lasted into July. June was hot, but July was not and this month also was rainy over long stretches.

During the summer 1338 heat was more dominant, it lasted together with drought throughout July and August. However, the spring had begun cold and hoar frost persisted throughout April. Rain came in the first week of May and in the second half of June. The dry parts of May and June were warm. The cold April slowed down vegetation growth and balanced out the warm end of the growing season, so that the mean temperature between April and July was on the whole average. The meteorological conditions during the growing season were excellent for grain cultivation, 1338 had one of the best harvests of the later Middle Ages.[24] Such a harvest success even found its way into the collective English memory. The most popular chronicles of the fourteenth and fifteenth centuries, the Brut, the Polychronicon and the London chronicles, all mention a very good farming year in the second half of the 1330s, some date it to 1337, but considering the grain price and Campbell's data

[23] Mortimer, William Merle's weather diary, 44–45.

[24] Campbell, Nature as historical protagonist, 299.

on harvest quantity[25] clearly 1338 is meant. Prices were also kept low by a scarcity of money and deflation. The Chronicle of London notes:

> Rex Edwardus Tertius, anno xj […] Also in this yere was gret plente of vitaile, that a quarter of whete was sold at London for ij s; and a fat oxe for vj s. viij d.; and vj pegons for a peny: but natheles it was ful gret scarcste of money.[26]

Spring 1339 followed on the hard winter 1338–1339.[27] Some cold weather still marked early April and the second half of May and the first half of June were rainy, but at least during most of April and from mid-June onwards it was warm, respectively hot.[28] As a result, the reconstructed growing season mean temperature in 1339 was lower than in the preceding years, but still average. The bad harvest 1339, which was caused a substantial rise in the grain price, was not so much due to the weather during spring and summer, but rather to the weather at sowing time in the preceding autumn, which was extremely wet, and made the soil 'watery'. The cold winter – frost lasted for 12 weeks and started in early December – then changed the appearance of the saturated fields into that of sheets of ice, and by spring 1339 most winter corn had perished. According to Merle the summer season 1339 was marked by higher rainfall levels than 1337 and 1338, but April – after the long winter the time for sowing the spring corn barley and oats – was very dry, which led to reduced yields in these crops (Appendix 1).[29] Hence, the year following the harvest 1339 was dire for the common people, and the rise of the price of grain would have been more decisive if it would not have been the time of a severe shortage of bullion.[30] Although no clear line can be drawn from the increase in poverty and malnutrition, it is probably not a mere coincidence that in summer 1340, before the next harvest, when provisions were at their lowest ebb and most expensive, a widespread disease took hold in England. It caused people great pain and made them emit sounds resembling those of barking dogs.[31]

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[25] Campbell, Nature as historical protagonist, 299.

[26] The Chronicle of London from 1089 [sic] to 1483, 56. A similar section is found in William Gregory's Chronicle of London, 80. The low prices of goods are also noted in the Brut, 292. A shorter version is contained in Higden, Polychronicon, vol. 8, 334 for spring 1339, but for the grain price with regard to the harvest 1338. The Polychronicon is the oldest text of the chronicles mentioned here.

[27] Merle, Consideraciones temperiei pro 7 annis, Titow, Evidence of weather, 397. This winter is also described as being long.

[28] Mortimer, William Merle's weather diary, 43. Further north in Staffordshire, the summer was wet, see Lynam (ed.), Croxden Chronicle, x. This description is obviously referring to the weather in late May and early June.

[29] Campbell, Great transition, 270–271.

[30] Murimuth, Continuatio Chronicarum, 88–89. Weather conditions are observed in detail in Merle, Consideraciones temperiei pro 7 annis, they entirely fit the description of Murimuth.

[31] Knighton, Chronicon, vol. 2, 36–37. Creighton, Epidemics in Britain, 59, considered the possibility of an outbreak of ergotism, but the harvest failure of winter grain in 1339 makes this unlikely. The editor of Knighton speculates about diphtheria, a throat infection, which could explain the barking voices, see Knighton, op. cit., 37.

The year 1340 (Sect. 8.1) followed the trend of increasing summer precipitation; the generally hot and dry weather was interspersed with a week of rain in May and two more wet weeks in July. However, the warm conditions were preceded by a cold and long winter. Merle reports frost well into April and occasional hoar frost throughout this month. As a result of the late start of the growing season the reconstructed East Anglian April–July temperature is average.

The coldest reconstructed growing season in the 1337–1343 period is 1341. Merle not only notes frost, snow and hoarfrost in the first half of April – his references to warm weather in the following months are few, only May had warm weather for more than a week – but Merle's references to rain are all the more frequent. This rather unpleasant growing season resulted in a late harvest, especially in northwestern Norfolk, where the cold April must have been felt keenly.[32] Although the cold and wet growing season did not impact severely on the harvest on a national level, the wheat harvest was poor on the Winchester manors in southern England.[33]

The trend of increased precipitation during the growing season continued in 1342. April and the first half of May are still characterized as mild or warm and dry by Merle. A few complaints about a dry spell in the Sussex accounts and the Pipe Roll of the Bishopric of Winchester refer to this period. Afterwards rainfall was frequent, especially in June and July.[34] In August precipitation levels remained high; southern England experienced some rainfall during the harvest.[35] Due to the prolonged dull and rainy period the reconstructed growing season temperature was fairly cool, but warmer than the previous year.

Rain was also a dominant feature in 1343. There was recurrent rainfall in April and May, the first three weeks of June witnessed light rainfall daily, the latter part of July was rainy and August also saw frequent rainfall, partly in the form of showers. According to Merle this rainfall at the end of July and later was a rather local phenomenon of northern Lincolnshire. Possibly this applies also to some of the precipitation in the earlier months, because some dry weather was then experienced in the Winchester area as well as in Sussex.[36] At the beginning of September Merle notes that in northern Lincolnshire he had not seen a single serene day in the preceding five weeks. The reconstructed growing season temperature was average, indicating that south of Lincolnshire was indeed not only wet and cool but also partly drier as warm air masses likely crossed over England.

[32] Even the Pipe Roll of the Bishopric of Winchester, normally a very informative source for meteorological conditions, hardly records any dry weather in 1341. Only one manor refers to it, another mentions 'waters in summer', Titow, Evidence on weather, 398.

[33] Campbell, Physical shocks, 25, Titow, Evidence on weather, 398.

[34] Brandon, Late medieval weather in Sussex, 3, Titow, Evidence on weather, 398. Mortimer, William Merle's weather diary, 45 considers Merle's diary, which is reporting generally wet conditions, and the manorial accounts of the Winchester estates and from Sussex, which are recording some dry weather for the growing season, as incompatible for 1342. However, April and May were considered as part of summer by the medieval agriculturalist, especially if the weather was fine, hence the reported dry spells in the accounts can refer to a dry period in April and May.

[35] Titow, Evidence on weather, 398.

[36] Titow, Evidence on weather, 398–399, Brandon, Late medieval weather in Sussex, 3.

Repeated thunderstorm references by Merle underline the high propensity for convective cell development that summer, which is connected to higher temperatures.

Although summer and partly also spring 1342 and 1343 were gloomy and rainy, the rainfall in England was not excessive and no floods are reported. In central Europe, however, the situation was catastrophic: the continuous rain caused a major crisis. Southern and eastern Germany, Switzerland, Austria and the Czech Lands were hit by a sequence of partly extreme flood waves in 1342[37] and the Carpathian Basin in 1343,[38] including the worst central European inundations of the last millennium, the St Mary Magdalene's Flood in July 1342.

Thus the reconstructed temperatures in East Anglia and the weather evidence provided by William Merle correspond largely and complement each other. Although it is difficult to estimate rainfall amounts from the 'precipitation days' given by William Merle,[39] it is obvious that precipitation levels were comparatively low in 1337 and 1338 and above average in 1341, 1342 and 1343. The increased humidity in 1341 and 1342 coincides with cooler spring and summer reconstructions.

[37] Brázdil, Kotyza, History of weather and climate (1000–1500), 168. Rohr, Extreme Naturereignisse im Ostalpenraum, 226–228.

[38] Kiss, Floods and weather in 1342 and 1343 in the Carpathian Basin.

[39] Lawrence, The earliest known journal of the weather, 498–499, compared the average monthly frequencies of rain days 1337–1343 with those for 1901–1930 and concludes that for May to October the two periods are comparable, November and December 1337–1343 are average or slightly below the average in 1901–1930, January to April are also below average.