

Central England temperatures: monthly means 1659 to 1973

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SUMMARY

An up-to-date Table is provided of the monthly and seasonal means representative of the air over central England from 1659 onward, incorporating some minor revisions and extensions of the earlier Table (Manley 1953 and 1959). Comments on its construction, and on the prospect of further extension backward in time, are added.

1. INTRODUCTION TO THE PROBLEM

Science has been said to proceed through a series of approximations of increasing precision. The first steps towards the precise instrumental measurement of the physical properties of the atmosphere in which we have to live were taking place towards the end of the sixteenth century, at a time when, as a consequence of the Age of Discovery, a very rapid increase in apprehension of the results of its behaviour was to be noted. Within England itself some of the first efforts to compare climates are to be found in those chapters 'Of the Air and Soil' by our early topographical writers on the several counties; for example in Harrison's prefatory chapter to *Holinshed's Chronicles*, first published in 1577. Four centuries later we are still accumulating observations that are still open to critical comment. For example we have over a hundred years of careful continuous recording of the temperature of the air within a large ventilated wooden box attached to the north wall of Kew Observatory, that does not represent more than an approximation to that of the air of riverside Surrey. Nearly 300 years ago, John Locke was likewise recording the temperature of the air in a large and quite well-ventilated box, in the form of a parlour within a house on the far side of Epping Forest (Locke 1705). This provided for posterity a rather more doubtful approximation to that of the air of Ongar, which in turn would at best merely approximate to that of Teddington or Richmond. Indeed, bearing in mind the extraordinary complexities attending the reduction of earlier temperature series, every one of which has been subject to the effects arising from the growth of the built-up area how can we provide a satisfactory long-term index of the temperature of the air for Londoners? To this must be added the consequences of changes in the hours of observation, or of setting when maxima and minima are recorded; of changes in the immediate vicinity of the instruments, such as appear to have affected even the Greenwich Observatory record; and, beyond these, undetected instrumental errors and the results of inadequately protected, or over-protected, exposures about which we have little or no information.

There is nevertheless considerable fascination in tackling the problem of integrating the longest possible sequence of quantitative meteorological data across those western European latitudes in which knowledge of climatic vicissitudes is likely to be sought and found rewarding by such a wide diversity of enquirers, from solar physicists through biologists and engineers to social economists. Temperature fluctuations provide the element with which the majority are first concerned. Especially since the recognition of the effects of the appreciable amelioration earlier in this century, efforts have been made to give better definition to the fluctuations through extending our tables of reliable monthly means back

in time. From several European countries and from eastern North America we have tables for 200 years; for Europe a comprehensive series of references has been given by von Rudloff (1967) and for the eastern United States by Landsberg, Yu and Huang (1968).

Provision of lengthy and reliable sequences of monthly means of pressure or totals of rainfall presents a different series of technical problems; in regard to pressure, Professor Lamb's vigorous effort in providing data back to 1760 is well known (Lamb and Johnson 1959).

2. ENGLISH TEMPERATURES: DIFFICULTIES OF STANDARDIZATION OF DIVERSE RECORDS

In 1953 in this Journal I presented a series of monthly means (1698–1952), with comments on method, representative of inland locations in the English midlands, and probably most closely matched by the results of observations kept at stations of intermediate character in open rural surroundings in the lowlands of Staffordshire, Shropshire, North Warwickshire ($52^{\circ} 30'$ to 53°N , $1^{\circ} 45'$ to $2^{\circ} 15' \text{W}$) at 100 to 200 feet above sea level. The term 'intermediate character' implies that they should not for example be located in acute frost-hollows, or on wide stretches of sandy soil, or exceptionally windswept ridges. Quite considerable differences in the published monthly means, compared with those at neighbouring stations, arise in such unusual sites. They abound in the *Monthly Weather Report*, and have often been discussed in the profuse literature on local climates, e.g. by the present author in the *Geographical Journal* (Manley 1944). To illustrate, it is enough to quote from the *Monthly Weather Report*, the differences in February 1936 of the mean monthly minima between the neighbouring stations at Rickmansworth (23.3°F) and St. Albans (30.0°F). In the dry anticyclonic March 1953 the mean minimum at Malham Tarn was 0.4°F above that at Ilkley, 300 m lower. Broadly, about six types of inland site can be quickly recognized: urban, favoured well-drained slopes, hilltop, lakeside, normal open lowland, frost-hollows, exceptional sandy soils. At some stations more than one factor is operative (e.g. at Edgbaston, Blackford Hill by Edinburgh, and Sheffield among those in the present *Monthly Weather Report*).

Because of these local differences, and the fact that in a crowded country such as England the immediate environmental characteristics of any meteorological station are increasingly liable to change, it is becoming neither practicable nor desirable to specify a precise location to which all observations can ultimately be standardized. Repeatedly one must have recourse to considered approximations whether in compounding a 'most probable mean temperature' from a triangle or a group of well-run stations lying across our midland counties today, or, 100 years ago, providing the best available corrections to monthly means of temperature deriving from stations that were then using the less perfect 'Glaisher Stand' for their thermometers, to bring them to Stevenson standards.

Suffice it to point today to the problems of comparison of the published monthly means in the Oxford region that are derived from '21 hr, 09 hr' (day max, night min) observations at the first-class airfields at Abingdon and Brize Norton, with those of the Radcliffe Observatory in Oxford itself (09 hr terminal) which since about 1935 shows signs of the growing effect of urbanization and slight changes of site; or with those other published means in the obviously frosty locations at Grendon Underwood and Medmenham, or the rather less frosty Wallingford or Aylesbury. All these stations lie within a few miles of Oxford at much the same level; which now provides the best representative monthly mean?

Enough has been said elsewhere (Manley 1941, 1946, 1952 for example) about the increasing need for careful approximation, based on detailed consideration of the actual daily records, when one is faced with the unorthodox exposures, fixed hour readings,

and gaps in records that plague the investigator of our bewilderingly diverse amateur records before the days of official meteorology. In general one starts by comparing such overlapping series as one can find, examining the hours of observation and the signs of radiation effects; and thereafter useful checks can be forthcoming from comparison of the observations made at the same time on particular days, for example in a strong warm south-wester in the winter. Still greater problems arise when before about 1760, some of the best-kept records depended on thermometers exposed in well-ventilated north-facing fireless rooms, following Jurin's injunction in 1723 (cf. Manley 1952, 1953, 1962). Lastly, before 1752 monthly means capable of comparison with those of England today, or those of contemporary western Europe, cannot be provided satisfactorily unless one has daily observations to cope with the change from the Julian to the Gregorian Calendar, not adopted in England ('New Style') until 1752, by which time the difference amounted to 11 days.

The decision to provide monthly means representative of central England was made because of (a) the inherent difficulties in any attempt to provide for the London area, for reasons already indicated; and (b) the fact that the Lower Thames Basin lies too much to one side to be closely representative of England more generally. Thirdly, the best long series of monthly means hitherto reduced, for any one place, derived from the south midland record kept from 1815 onward at the Radcliffe Observatory at Oxford (Knox-Shaw and Balk 1932) which could be bracketed with the present writer's Lancashire Plain series beginning in 1753 (Manley 1946) to give something representative of the west midland counties lying between. Moreover, there are particularly valuable overlapping records kept by Thomas Barker at Lyndon in Rutland (1736-1798) lying well within the midlands, together with George Lynn's record near Oundle (1726-early 1740) and others such as Dr. Thomas Hughes near Stroud (1771-1813) or Dr. Thomas Short at Sheffield (1734-1956). A study of the normal isotherms over England justifies this process. References and manuscript sources are listed below.

Back to 1723 it is always possible to bracket an approximate monthly mean for a central English location; the basic material being relatively weakest in 1750-1751 and 1765-1766. But before 1723 we have a very troublesome gap, as far as temperature observations are concerned, over the period January 1707 to October 1722. Before 1707 practically all the sequences of daily observations of temperature that have survived, from 1671 onward were kept in London or in the country nearby (e.g. Upminster 1699-1706; Oates, near Ongar, 1692-1703). There is, however, a brief Oxford instrumental record (MS.) kept by Locke, March 1666-May 1667, apparently the earliest daily sequence that we possess; and there is another from Wrentham in Suffolk, kept by Skippon, 1673-1675 (Margary 1927). With regard to the baffling gap 1707-1722, there is evidence that some at least of the early thermometric observations sent in to the Royal Society were destroyed as 'of no further use' (*Philos. Trans.*, 24, 1707, p. 347; *Symons Magazine*, 59, 1924, pp. 183-184). This gap was filled by reference to the Utrecht series (Labrijn 1945) adjusted as far as possible from consideration of English non-instrumental 'wind and weather' diaries over that period: for a few months in 1707 some scanty observations of temperature by Henry Beighton (MS., British Museum) were of assistance.

3. OBJECT OF THIS PAPER

The purpose of this paper, after the lapse of 20 years, is first: to reprint the table of monthly means and to bring it up to date. The frequency with which the table has been referred to in discussions of climatic fluctuations would appear to justify the reprinting. Second: to incorporate in one table the additional values before 1698 for central England,

rounded to 0.5 deg C, that have been derived from several earlier series of London observations between 1670 and 1697 that have already been reduced and published (Manley 1961, 1962, 1963). Third: to bring into one table the revised values over the years 1699–1706 that have been published as a result of my reconsideration of William Derham's very carefully drawn-up manuscript daily observations now in the Royal Society's library. Fourth: to incorporate in the light of more recent discoveries in MS., hitherto unrecorded, some improvement on the estimates that were previously made to cover the months from 1707 to 1722. The scattered series of old temperature observations from various parts of the country that continue to be found in collections can now be compared with a 'working standard'. Lastly: the provision of an indication of principal sources may be of service to others who no doubt in time will wish to improve, in the light of subsequent findings, on the monthly means given in this Table which from 1815 to 1957 derives from half the sum of Oxford, after applying the 'Radcliffe' corrections, plus 'Lancashire' as described in the 1953 paper. These 'Radcliffe' corrections were calculated (Know-Shaw and Balk 1932) in order to provide an adjustment of the Oxford observations, as published, to 24-hour means.

4. NOTE ON UPDATING OF MONTHLY MEANS TO 1973

A further reason for bringing this Table up to date lies in the fact that careful cross-comparison indicates that temperatures observed at the long-standing and well-regarded Radcliffe Observatory at Oxford are gradually becoming less representative, notably since about 1960; this is probably in the main attributable to growth of the city. Differences are as yet small, but in future it would appear to be preferable to derive a central England monthly mean, by using in place of 'Oxford' as hitherto adjusted, the average from two or more apparently reliable 'institutional' south midland stations such as Rothamsted and Abingdon. Indeed, the mean directly derived from the four stations Rothamsted, Shinfield, Abingdon, and Cirencester plus 0.4, makes a good representation. This can be combined with the mean of Lancaster, Kirkham, Preston and Stonyhurst plus 0.6. There may be advantage if well-maintained 'institutional' records from good sites are used. In Staffordshire, Keele University provides a particularly well-maintained station in 'central England' that might well be commended, were it not for the fact that the correction that must be applied for the altitude of the station (587 ft) varies not only with the months but also with the meteorological character of the month, in greater measure than if the station were more 'lowland'. Elsewhere: in Shropshire, Shawbury appears to have been affected by a change of site; other well-established midland sites such as Newport (Harper Adams College) and Sutton Bonington appear to be 'frosty' with noticeably low minima.

Let it be remembered that what may appear to be a somewhat fussy procedure in deriving a mean is desirable, as climatic fluctuations are small and over decades tend to be measured in tenths of a degree. Indeed, in the analysis of recently published Oxford data the coarseness of the unit that is now provided by the Celsius degree has become evident when making comparisons. I am indebted to Dr. C. G. Smith of Keble College and the School of Geography, for drawing my attention some years ago to the tendency for the Oxford monthly means to rise relative to others; it appears that the night minima are most affected, which supports the view that the 'urban effect' is increasing (Smith 1967). In bringing the table up to date I have allowed a small adjustment for this since 1960, deducting between 0.1 and 0.2 deg F in the majority of months from the published Oxford mean, after consideration of Abingdon, Brize Norton and Sherburn in the adjacent countryside.

TABLE 1. CENTRAL ENGLAND: MONTHLY MEANS FOR AIR TEMPERATURE, 1659-1972 (°C). (GREGORIAN OR NEW STYLE CALENDAR THROUGHOUT)

For the first six decades to 1720 the figures are printed in italics as an indication that they must be considered less reliable, based as they are on extrapolation from the results of readings of highly imperfect instruments in uncertain exposures at a considerable distance, generally in south-east England; or on estimates based on interpretations of daily observations of wind and weather. Until June 1666 and from October 1667 to October 1668 daily observations are largely lacking. Before 1671 instrumental readings are few; accordingly all values before 1671 have been rounded to whole degrees C. Regular thermometer readings begin again in 1672.

From 1671 onward more than one series of daily wind-and-weather observations are in general available and the majority of monthly means have been rounded to 0.5 deg C. Estimates, however, are still necessary for much of 1671, for July 1677 to August 1678, June to August and November 1695, June and November 1696, June 1697. From 1707 onward, although there are several English sets of daily observations in increasing detail, and these now include northern England, very few thermometer readings have yet been found. A general control for 1707-1722 is best established from a careful analysis of observed snowfall frequency and from the overlapping series of monthly means representative of Utrecht in Holland, coupled with wind directions. Values from central England for 1707-1722 are again rounded to 0.5 deg C.

	J	F	M	A	M	J	J	A	S	O	N	D	Year
1659	3	4	6	7	11	13	16	16	13	10	5	2	8.8
1660	0	4	6	9	11	14	15	16	13	10	6	5	9.1
1661	5	5	6	8	11	14	15	15	13	11	8	6	9.1
1662	5	6	6	8	11	15	15	15	13	11	6	3	9.5
1663	1	1	5	7	10	14	15	15	13	10	7	5	8.6
1664	4	5	5	8	11	15	16	16	13	9	6	4	9.3
1665	1	1	5	7	10	14	16	15	13	9	6	2	8.3
1666	4	5	6	8	11	15	18	17	14	11	6	3	9.8
1667	0	4	<2	7	10	15	17	16	13	9	6	3	8.7
1668	5	5	5	8	10	14	16	16	14	10	6	5	9.5
1669	1	4	5	7	11	15	17	16	14	10	6	2	9.0
1670	3	<1	5	8	11	14	16	16	14	10	6	3	8.9
1671	4	3.5	5	7.5	11.5	13.5	16	15.5	13.5	8.5	6	4	9.1
1672	1.5	1.5	5	7	12	16	15	14	11	11.5	6.5	4.5	8.9
1673	5	1.5	5.5	7	11	14.5	15.5	15.5	11.5	7.5	5	0.5	8.7
1674	5	2	>1	7.5	11	13.5	14	13.5	10.5	9	6.5	3.5	8.2
1675	3	2	3	7	10.5	11.5	15	14.5	10.5	8	4.5	4.5	7.9
1676	5.5	5	5	7.5	10.5	18	16	16.5	12	7	3.5	-0.5	8.8
1677	3	3.5	7	7.5	10	13	18	15	13	8.5	4.5	2	8.7
1678	1.5	2	4	6.5	11	14.5	16.5	15	15	8.5	6	0.5	8.5
1679	1	1.5	4.5	7	12	15.5	16	17	13	11	3.5	2.5	8.8
1680	3.5	3.5	6	6.5	10.5	13	16	15	14.5	10.5	6.5	1	8.8
1681	0.5	1.5	4	8	10.5	14	15	16	14	11.5	6.5	3	8.7
1682	6	2	4.5	6.5	11.5	14	15	14.5	13	9.5	5.5	6	9.0
1683	3.5	2	5.5	9.5	11.5	16	15.5	13.5	13	6.5	4.5	0.5	8.5
1684	-3	-1	3	6.5	13	15	16	15.5	12	11	3	4	7.9
1685	0.5	3.5	5	8.5	12.5	14.5	14	14.5	11.5	11.5	7	6.5	9.1
1686	6.5	6	7	8.5	12.5	15.5	16.5	14.5	13	9	6.5	6	10.2
1687	3.5	4.5	4.5	6.5	11	13	15.5	15	11	11	6	6	8.8
1688	3.5	1.5	3.5	5.5	10.5	13	15.5	15	12	7	4	3	7.8
1689	0.5	4.5	5	8	11	12	15.5	15.5	13	8	5	4.5	8.5
1690	4	4.5	4.5	8	9.5	13.5	15.5	15	13	8.5	6.5	4.5	8.9
1691	1	1	5	6.5	10	14.5	15.5	15.5	11	9	5	3.5	8.0
1692	2	0	4	7.5	9	13.5	15	15	11.5	6.5	5	3.5	7.7
1693	3	5	3	6.5	9	14.5	15	15	12	9.5	6	3	8.4
1694	0	5	3.5	7.5	9	13	15	13	10.5	7.5	5.5	2.5	7.7
1695	-1	0.5	3.5	5.5	9	13	13.5	13	11.5	9	5.5	4	7.2
1696	5.5	4.5	3.5	5.5	10.5	13	15.5	15.5	11.5	9	5.5	2.5	8.5
1697	1	0.5	5.5	7	11.5	13	15.5	14.5	12	9	4	2.5	8.0
1698	0	0.5	3.5	7.5	8.5	12	15	15	13	9	4	3.5	7.7
1699	3.4	3.4	3.9	6.4	10.0	14.4	17.2	15.0	13.3	9.4	5.6	3.6	8.8
1700	3.9	2.5	3.6	6.4	12.0	13.6	15.0	15.0	12.8	8.9	5.0	4.2	9.1

	J	F	M	A	M	J	J	A	S	O	N	D	Year
1701	2.8	2.5	2.8	4.7	10.9	14.2	18.3	16.1	14.7	7.5	6.4	3.6	8.7
1702	5.0	6.7	5.8	5.8	10.6	13.3	15.0	16.1	14.4	10.0	4.4	4.4	9.3
1703	2.2	3.9	5.6	8.3	11.9	13.9	16.1	16.1	10.6	7.8	7.2	5.1	9.1
1704	2.0	3.3	5.3	8.3	11.5	14.4	16.7	16.9	11.9	8.3	6.4	3.6	9.1
1705	2.8	3.9	4.4	7.8	11.2	12.2	15.6	17.5	11.9	8.9	3.9	4.4	8.7
1706	2.8	4.2	6.4	8.9	12.2	15.6	16.1	16.7	12.5	11.2	6.1	4.7	9.8
1707	3.5	3.0	5.0	8.5	11.0	16.0	17.0	16.0	14.0	8.5	6.5	3.5	9.4
1708	6.0	4.0	6.5	9.5	10.5	14.0	15.0	17.0	15.0	8.5	7.0	3.0	9.7
1709	1.5	2.0	3.0	9.0	12.0	14.5	15.5	15.5	13.5	10.0	7.5	3.5	8.7
1710	2.5	3.5	6.0	6.5	11.5	14.5	15.0	15.5	13.5	9.5	8.0	7.5	9.5
1711	5.0	2.0	5.5	9.5	11.0	15.5	15.5	15.0	13.0	9.5	7.0	4.0	9.4
1712	3.0	4.5	5.0	7.5	11.0	15.0	16.0	15.0	13.0	9.5	6.0	4.0	9.1
1713	3.0	5.5	4.5	5.5	10.5	13.5	14.0	15.0	14.0	9.5	4.5	4.0	8.6
1714	4.0	5.5	5.0	7.5	10.0	14.5	18.0	15.0	13.0	10.5	6.0	4.0	9.4
1715	4.0	5.0	6.5	9.5	11.0	14.0	15.5	15.0	14.0	10.5	6.5	1.5	9.4
1716	2.0	3.0	4.5	9.0	10.5	14.0	15.5	15.5	12.5	9.5	5.5	3.0	8.4
1717	4.5	2.5	4.5	7.5	11.0	14.0	15.0	15.5	13.5	9.5	5.5	5.0	9.0
1718	1.5	3.0	5.5	7.5	11.0	14.5	17.0	17.0	14.5	9.5	5.5	4.5	9.3
1719	3.0	4.0	5.0	7.0	11.5	15.0	18.0	17.0	14.0	9.5	6.0	3.5	9.5
1720	4.5	4.0	4.0	7.5	11.0	13.0	16.0	15.0	13.5	9.0	6.0	5.5	9.1
1721	4.0	2.0	3.5	8.5	9.5	14.0	15.5	16.0	14.0	9.0	6.0	4.5	8.9
1722	4.0	5.0	6.0	7.5	10.5	14.0	15.0	15.0	13.5	10.0	7.8	3.9	9.3
1723	1.1	4.4	7.5	8.9	11.7	15.0	15.3	15.6	13.3	11.1	7.5	5.8	9.8
1724	5.6	4.2	4.7	7.2	11.4	15.3	15.0	16.2	14.4	8.6	5.3	3.3	9.3
1725	4.4	3.3	5.0	8.1	10.8	12.2	13.8	13.3	12.8	9.4	6.9	3.9	8.7
1726	1.1	4.2	4.2	8.4	13.4	16.4	16.0	15.6	14.7	10.2	6.1	1.8	9.3
1727	4.2	5.0	5.1	9.2	13.6	14.9	16.9	16.9	14.4	10.8	4.7	3.6	9.9
1728	3.9	2.4	7.1	8.3	12.5	16.4	16.9	16.0	12.8	9.1	7.2	1.6	9.5
1729	1.2	2.3	2.8	7.1	10.3	15.1	16.8	15.7	16.6	10.1	8.1	5.0	9.3
1730	4.1	4.7	6.2	8.7	12.4	14.0	15.3	16.3	15.3	10.9	9.2	3.4	10.1
1731	1.9	2.2	6.0	6.8	12.1	15.6	16.3	16.7	15.3	12.3	7.8	5.2	9.8
1732	2.4	6.4	6.1	8.9	11.4	14.6	16.0	16.6	14.5	10.9	6.3	2.2	9.7
1733	6.9	6.0	5.9	10.0	11.2	15.2	18.3	16.1	12.8	9.1	6.5	7.6	10.4
1734	4.3	6.4	8.1	9.3	11.1	14.1	16.2	16.2	13.3	8.4	6.2	4.0	9.8
1735	4.4	4.0	5.8	8.9	10.9	13.3	14.8	16.2	14.2	10.3	6.3	5.4	9.6
1736	6.4	3.1	6.9	8.6	10.6	15.7	16.4	17.8	14.4	10.4	6.9	6.4	10.3
1737	6.2	4.2	6.1	8.8	12.5	15.9	17.4	13.8	14.2	8.9	6.1	4.9	9.9
1738	4.6	4.6	5.5	9.9	11.4	14.2	16.4	16.0	12.5	10.2	6.3	6.1	9.8
1739	4.0	6.8	5.8	6.7	11.6	15.2	16.0	14.7	13.1	9.6	3.7	3.2	9.2
1740	2.8	1.6	3.9	6.4	8.6	12.8	15.3	14.7	14.0	5.3	3.3	2.2	6.8
1741	1.7	4.4	4.2	7.1	9.3	15.2	15.6	16.7	14.7	11.0	7.8	3.9	9.2
1742	1.9	3.6	4.1	6.6	10.6	15.0	15.8	15.8	12.2	9.2	4.4	1.1	8.4
1743	3.6	5.4	5.3	5.4	13.3	15.6	14.9	16.9	14.2	8.9	9.3	4.9	9.8
1744	1.4	2.9	4.8	6.7	10.8	14.4	16.4	15.4	12.8	9.4	6.9	3.5	8.8
1745	3.8	2.3	4.4	7.5	11.4	12.2	16.1	15.0	14.2	10.3	5.8	2.7	8.8
1746	2.5	1.4	3.1	6.9	12.8	14.3	15.8	15.9	14.2	7.8	3.3	5.3	8.6
1747	3.3	5.8	2.5	8.1	12.2	14.7	16.9	18.3	14.4	9.4	6.9	5.3	9.8
1748	2.5	1.8	1.8	6.3	10.4	14.8	15.4	15.8	14.2	9.2	7.1	6.0	8.8
1749	5.3	3.6	5.3	6.8	12.3	11.9	17.2	15.6	13.8	10.1	6.7	4.7	9.4
1750	4.0	6.7	8.2	7.7	10.7	14.2	17.2	15.0	15.2	9.2	4.0	4.2	9.7
1751	4.0	1.5	6.2	7.1	9.3	14.9	15.3	14.6	12.6	8.3	4.3	3.0	8.4
1752	3.2	3.1	5.6	6.8	10.3	14.8	15.6	15.7	13.9	10.6	6.5	4.2	9.2
1753	2.2	3.6	6.0	7.5	12.1	14.6	15.2	15.7	13.1	10.0	4.6	4.4	9.0
1754	3.3	2.8	3.4	6.7	12.2	13.6	14.7	15.7	13.9	10.4	5.7	3.6	8.8
1755	2.2	1.2	3.9	10.0	9.4	15.7	15.0	14.6	13.5	8.4	4.7	3.9	8.6
1756	4.4	4.6	6.0	6.7	9.1	13.8	16.1	14.7	13.6	9.4	3.9	2.9	8.8
1757	0.3	4.0	4.9	8.1	10.7	14.0	18.4	15.2	13.3	8.2	7.1	3.2	8.8
1758	2.6	3.8	5.2	7.2	13.8	14.6	14.2	16.4	11.9	8.1	5.7	3.9	9.0
1759	5.9	5.8	6.1	8.6	12.1	15.0	18.2	16.3	13.5	10.9	5.1	2.5	10.0
1760	1.9	3.8	6.6	9.4	11.7	15.2	16.9	15.8	15.7	9.2	5.7	6.1	9.8

	J	F	M	A	M	J	J	A	S	O	N	D	Year
1761	5.4	5.8	6.8	9.4	11.9	14.3	15.8	16.4	14.2	9.4	6.2	4.4	10.0
1762	4.7	4.0	3.7	10.0	12.9	16.9	17.8	15.3	13.6	7.9	4.6	3.6	9.6
1763	-0.8	4.9	5.4	8.9	10.2	14.6	15.3	15.3	13.1	8.3	5.8	6.2	8.9
1764	3.7	3.8	3.9	7.2	12.2	13.9	16.1	15.2	12.5	8.9	4.4	2.8	8.7
1765	4.8	0.4	5.0	7.5	11.4	13.8	15.7	15.3	13.3	9.2	3.9	1.7	8.5
1766	0.7	1.7	4.2	8.1	9.7	13.7	15.7	16.6	13.3	9.3	7.2	3.3	8.6
1767	0.1	5.4	4.7	7.3	10.0	12.8	14.4	16.1	14.1	9.2	6.9	3.3	8.7
1768	0.8	4.8	4.7	8.1	12.2	13.9	15.6	16.0	11.7	9.2	5.6	4.6	8.9
1769	2.5	2.7	5.0	7.8	11.3	13.1	16.4	15.0	12.8	8.2	5.7	4.8	8.8
1770	3.7	4.6	2.5	5.4	10.0	13.1	15.3	15.8	13.9	8.9	5.3	3.6	8.5
1771	1.0	3.2	3.1	5.5	12.2	14.3	15.7	14.3	12.2	9.2	6.3	5.6	8.6
1772	1.2	1.9	4.4	6.4	10.1	16.1	16.9	16.1	13.0	11.7	7.2	4.8	9.2
1773	4.0	2.6	6.5	8.3	10.3	14.7	15.9	17.2	12.4	9.9	5.3	3.8	9.2
1774	0.6	4.3	6.4	8.6	10.9	14.7	16.1	16.1	12.5	10.3	4.8	3.5	9.1
1775	4.6	6.1	6.0	9.8	12.6	16.6	16.7	15.8	14.3	9.3	4.8	4.5	10.1
1776	-1.6	3.8	6.4	9.4	10.8	14.1	16.3	15.2	12.9	10.2	6.2	4.4	9.0
1777	1.9	2.3	6.8	7.2	11.7	13.6	15.3	15.9	14.6	10.2	6.9	2.6	9.1
1778	1.9	3.2	4.6	8.2	10.6	15.4	17.3	16.8	12.2	7.4	6.7	6.1	9.3
1779	2.9	7.9	7.9	9.4	11.9	14.4	17.9	17.6	15.2	10.9	5.7	3.1	10.4
1780	-0.9	2.1	7.9	6.3	12.8	14.2	16.8	17.6	15.6	9.1	4.4	3.2	9.1
1781	2.1	4.8	6.6	9.2	12.1	16.2	17.4	17.3	14.2	10.6	6.5	5.4	10.2
1782	5.2	1.9	4.1	5.2	9.0	14.9	15.6	14.2	13.3	7.6	2.3	2.8	8.0
1783	3.4	3.3	3.3	10.1	10.4	14.8	18.8	15.8	12.8	9.8	6.2	2.7	9.3
1784	-0.6	1.4	2.7	5.7	13.5	13.7	15.2	14.0	14.8	7.8	5.5	0.3	7.8
1785	3.4	0.4	1.2	8.4	12.3	16.1	16.1	13.9	13.6	8.7	5.6	2.8	8.6
1786	2.7	3.4	2.1	8.1	11.2	16.1	15.0	15.1	11.7	7.5	3.3	2.8	8.2
1787	3.6	5.9	6.8	7.4	11.5	13.9	15.8	15.6	12.8	9.8	4.5	3.8	9.3
1788	3.9	3.8	3.6	9.4	13.8	15.4	15.8	15.8	13.4	9.8	6.1	-0.3	9.2
1789	1.5	5.0	2.1	7.4	12.5	14.0	15.4	16.6	13.1	8.6	4.6	6.1	8.9
1790	4.3	6.6	6.4	6.1	11.9	14.6	14.9	15.6	12.2	10.3	6.1	4.3	9.4
1791	4.3	4.7	6.5	9.6	10.6	14.7	15.3	15.9	13.8	8.9	5.9	1.1	9.3
1792	2.3	4.5	5.9	10.0	10.2	13.2	15.3	16.9	11.8	8.8	7.1	4.3	9.2
1793	2.8	4.6	4.2	6.2	10.9	13.5	17.6	15.0	11.7	11.3	6.0	5.3	9.1
1794	1.8	7.2	7.0	10.2	11.3	15.7	18.1	15.5	12.5	9.6	6.1	3.7	9.9
1795	-3.1	0.8	3.9	7.7	10.9	13.2	15.2	16.6	16.0	11.7	4.5	6.6	8.7
1796	7.3	4.7	4.2	10.2	10.3	13.9	14.7	15.9	14.6	8.1	4.6	-0.3	9.0
1797	3.5	4.6	4.3	7.4	11.3	13.6	17.3	15.8	12.5	8.2	4.7	4.8	9.0
1798	3.6	4.0	5.1	10.4	12.9	16.9	16.3	16.4	13.6	9.9	4.7	1.5	9.6
1799	1.7	2.8	3.4	5.4	9.6	14.1	15.2	14.4	12.9	8.3	5.6	1.3	7.9
1800	2.8	2.2	4.0	9.3	12.3	13.9	17.7	16.8	13.9	9.2	5.4	3.3	9.3
1801	4.6	4.8	6.7	8.3	12.1	14.8	16.1	17.1	14.2	10.2	4.8	1.5	9.8
1802	1.6	3.7	5.6	8.9	10.6	13.7	13.5	17.2	13.8	10.1	5.1	3.6	8.9
1803	1.8	3.4	6.3	9.1	10.5	13.7	17.6	16.1	11.4	9.3	5.0	4.4	9.1
1804	5.8	2.9	4.7	6.9	13.3	16.1	15.9	15.6	14.2	10.7	6.6	2.1	9.6
1805	2.1	4.1	6.2	8.3	10.2	13.2	16.0	16.4	14.6	8.2	4.8	3.6	8.9
1806	4.2	4.3	5.1	6.8	12.1	14.9	15.4	16.2	13.4	10.6	7.8	6.8	9.8
1807	2.8	3.7	2.9	7.7	11.8	14.2	17.1	16.9	10.5	11.4	2.9	1.9	8.7
1808	2.6	2.8	3.2	5.8	13.7	14.8	18.4	16.7	12.7	7.2	6.0	2.2	8.8
1809	2.0	5.7	6.0	5.2	13.1	13.7	15.1	14.8	12.7	10.2	4.6	4.1	8.9
1810	2.2	3.5	4.9	8.2	9.2	14.6	15.2	14.6	13.9	9.8	5.4	3.6	8.8
1811	1.2	4.6	7.1	8.9	12.8	14.1	16.1	14.4	13.7	12.3	7.7	3.1	9.7
1812	2.6	5.3	3.5	5.5	10.9	13.0	14.2	14.3	13.2	9.3	4.9	1.7	8.2
1813	1.9	5.8	6.8	7.6	11.6	13.6	15.0	14.5	12.5	8.1	4.3	2.8	8.7
1814	-2.9	1.4	2.9	9.6	9.2	12.2	16.0	14.7	12.8	8.1	4.7	4.3	7.7
1815	0.3	6.5	7.3	8.1	12.6	14.3	14.9	15.3	13.4	10.3	3.4	2.3	9.1
1816	2.7	2.1	3.9	6.6	9.9	12.8	13.4	13.9	11.8	10.3	3.9	3.1	7.8
1817	4.5	6.4	5.5	7.6	8.7	15.1	14.1	13.6	13.2	6.4	9.1	2.5	8.9
1818	4.4	2.7	4.5	6.9	11.3	16.4	18.2	15.3	13.3	12.0	9.5	3.6	9.8
1819	4.4	4.3	6.8	8.6	11.5	13.4	16.4	17.4	13.4	9.1	4.1	1.4	9.2
1820	-0.3	3.2	4.7	8.9	11.4	13.6	15.7	14.7	12.3	8.1	5.6	4.7	8.6

	J	F	M	A	M	J	J	A	S	O	N	D	Year
1821	3.6	2.1	5.7	9.5	9.4	12.3	14.8	16.4	14.9	10.4	8.6	6.4	9.5
1822	4.7	6.3	7.8	8.3	12.7	17.1	15.6	15.2	12.4	10.7	8.2	1.6	10.1
1823	-0.1	3.1	5.0	6.7	12.2	12.3	14.1	14.4	12.5	8.4	7.1	4.8	8.4
1824	4.3	4.7	4.6	7.4	10.7	13.4	16.0	15.1	13.7	9.5	7.2	5.1	9.3
1825	3.8	3.9	5.0	9.1	11.6	14.1	17.2	16.3	15.1	10.8	5.2	4.6	9.7
1826	0.4	6.4	6.3	8.8	11.2	17.3	17.9	17.6	13.6	11.1	4.4	5.8	10.1
1827	1.7	0.7	5.9	8.9	11.9	14.2	16.5	14.8	13.7	11.4	6.9	6.9	9.5
1828	5.1	5.2	6.6	8.3	12.4	15.4	16.0	15.3	14.3	10.2	7.4	7.4	10.3
1829	0.3	4.3	4.3	6.7	12.5	14.9	15.1	14.3	11.3	8.3	4.5	1.4	8.2
1830	-0.2	2.2	7.7	8.9	12.0	12.7	16.2	13.7	11.9	10.4	6.9	1.8	8.7
1831	1.6	4.8	7.2	9.2	11.5	15.4	16.7	16.9	13.7	12.7	5.6	5.8	10.1
1832	3.1	3.4	5.8	8.6	10.9	15.2	15.9	15.4	13.6	10.7	5.9	5.2	9.5
1833	1.2	5.6	3.9	7.7	15.1	14.6	15.8	14.3	12.1	10.1	6.6	6.9	9.5
1834	7.1	5.6	7.1	7.7	13.0	15.4	16.9	16.2	13.8	10.6	6.7	5.6	10.4
1835	2.9	5.7	5.8	8.6	11.3	15.0	16.4	16.9	13.4	8.9	6.6	3.1	9.6
1836	3.7	3.5	5.8	7.2	11.1	15.3	15.4	14.6	11.7	8.6	5.3	4.1	8.8
1837	2.7	4.7	2.3	4.7	9.9	15.5	16.9	15.7	12.5	10.5	5.2	5.3	8.8
1838	-1.5	0.4	4.9	6.1	10.5	14.4	15.6	15.1	12.7	9.8	4.6	4.0	8.1
1839	2.8	4.1	4.2	6.4	10.2	14.3	14.9	14.6	12.4	9.3	7.3	3.7	8.7
1840	4.1	3.6	3.8	9.7	11.4	14.1	13.8	15.9	11.1	7.5	5.8	1.3	8.5
1841	1.1	2.4	7.5	7.8	12.7	12.9	13.8	14.6	13.4	8.7	5.2	4.4	8.7
1842	0.6	4.2	6.4	7.8	11.4	15.6	14.5	17.1	13.2	7.2	5.5	7.2	9.2
1843	4.0	1.9	5.6	8.5	10.4	12.8	14.8	15.3	14.4	7.9	5.7	7.4	9.1
1844	3.8	1.6	4.7	9.8	10.8	14.7	15.4	13.5	13.3	9.2	5.9	0.4	8.6
1845	3.2	0.9	2.0	8.6	9.5	14.9	14.3	13.5	11.4	9.5	6.7	4.6	8.3
1846	6.3	6.4	6.1	7.8	12.3	18.2	16.5	16.6	14.7	9.5	6.9	0.5	10.2
1847	2.2	2.4	5.6	6.6	12.3	13.9	17.5	15.2	11.5	10.7	7.9	4.8	9.2
1848	1.3	6.1	5.9	8.2	13.9	14.5	15.6	13.6	12.8	9.7	5.8	5.6	9.4
1849	3.9	5.7	6.1	6.4	12.1	13.9	15.4	15.6	13.3	9.2	6.6	3.4	9.3
1850	0.7	6.4	4.7	9.0	10.1	15.4	16.2	14.5	12.3	7.9	7.4	4.6	9.1
1851	5.6	4.7	5.8	7.4	10.4	14.3	14.6	15.5	12.7	10.8	3.1	4.8	9.1
1852	4.9	4.7	5.2	8.2	10.6	13.2	18.7	15.8	12.9	7.8	7.9	7.7	9.8
1853	5.1	0.6	3.4	7.6	10.9	14.3	14.9	14.7	12.3	10.1	5.2	1.3	8.3
1854	3.6	4.3	6.7	9.2	10.3	13.2	15.4	15.2	14.4	9.4	4.9	5.1	9.3
1855	2.4	-1.7	3.3	7.1	8.8	13.3	16.8	15.7	13.2	9.7	5.3	2.4	8.0
1856	3.7	5.3	4.4	8.1	9.4	13.5	15.3	16.9	12.5	10.7	4.8	4.4	9.2
1857	2.6	4.3	5.3	7.5	11.3	15.8	16.4	17.4	14.5	11.3	7.2	7.3	10.1
1858	3.4	1.8	4.9	7.7	10.8	16.8	14.8	15.8	14.7	9.6	4.3	4.8	9.2
1859	4.9	5.7	7.3	7.5	11.7	14.8	18.3	16.2	12.9	9.6	4.8	1.6	9.6
1860	3.5	1.7	4.7	5.9	11.5	12.3	14.5	13.6	11.2	9.8	4.5	1.5	7.9
1861	1.7	4.9	6.3	7.5	10.4	14.8	15.0	15.9	13.1	11.8	4.2	3.9	9.1
1862	3.9	5.1	5.5	8.8	12.3	12.7	14.2	14.6	13.0	10.3	3.2	6.5	9.2
1863	4.9	5.8	6.5	8.8	10.6	13.6	15.2	15.5	11.6	9.9	7.3	6.3	9.7
1864	2.4	2.3	4.7	8.8	12.4	13.6	15.5	14.2	13.3	9.8	5.5	3.7	8.8
1865	2.1	2.3	2.9	10.6	12.6	15.6	16.6	15.1	16.3	9.7	6.7	5.8	9.7
1866	5.8	4.4	4.8	8.6	10.0	15.5	15.5	14.7	12.8	10.7	6.9	6.1	9.7
1867	1.2	6.9	3.1	9.3	11.4	14.1	14.9	16.3	13.6	9.3	4.8	3.4	9.0
1868	3.9	6.3	6.8	8.7	13.5	15.5	18.3	16.8	14.3	8.4	4.9	7.2	10.4
1869	5.6	7.5	3.8	10.1	9.6	13.2	17.3	15.5	14.4	9.7	5.8	2.9	9.6
1870	3.3	2.8	4.7	9.2	11.7	15.2	17.5	15.7	12.9	9.5	4.7	0.6	9.0
1871	0.5	6.1	7.3	8.7	11.3	12.8	15.2	17.2	12.7	9.8	3.4	3.6	9.1
1872	5.0	6.9	6.8	8.2	9.7	14.1	17.1	15.3	13.2	8.4	7.0	5.3	9.7
1873	5.2	1.8	5.4	7.7	9.9	14.2	16.2	15.4	11.8	8.6	6.3	5.3	9.0
1874	5.5	3.9	6.7	9.8	10.0	13.9	17.3	15.1	13.6	10.4	5.6	-0.2	9.3
1875	6.4	2.3	5.1	8.6	12.3	14.2	14.8	16.1	14.9	8.9	5.4	4.2	9.4
1876	3.2	4.8	4.5	7.9	9.6	14.3	17.2	16.5	12.7	11.3	6.1	6.0	9.5
1877	5.5	6.2	4.9	7.0	9.1	15.2	14.7	15.2	11.2	9.3	7.1	4.7	9.2
1878	4.6	5.6	5.4	8.9	11.8	15.1	16.6	16.2	13.3	10.2	3.5	-0.3	9.2
1879	-0.7	3.1	4.7	5.7	8.9	12.9	13.6	14.5	12.6	8.9	4.1	0.7	7.4
1880	0.9	5.8	6.2	7.9	10.4	13.8	15.5	16.4	14.6	7.1	5.4	5.1	9.1

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	J	F	M	A	M	J	J	A	S	O	N	D	Year
1881	-1.5	3.2	5.3	7.3	11.8	13.7	16.2	13.9	12.7	7.3	8.9	3.9	8.6
1882	5.2	6.1	7.4	8.4	11.5	13.1	15.2	14.9	12.1	9.9	5.7	3.9	9.4
1883	4.7	5.9	1.9	8.1	10.6	13.9	14.5	15.3	13.3	9.7	5.8	4.6	9.1
1884	6.5	5.3	6.5	7.2	11.3	14.1	16.3	17.2	14.5	9.4	5.3	4.4	9.8
1885	2.9	5.8	4.5	7.7	8.9	13.9	16.3	13.6	12.2	7.5	5.9	3.7	8.6
1886	2.1	1.5	4.2	7.6	10.3	13.6	15.9	15.8	13.6	11.3	6.6	1.9	8.7
1887	2.4	3.8	3.3	6.2	9.4	15.3	17.3	15.7	11.8	7.1	4.4	2.6	8.3
1888	3.2	1.8	3.1	6.2	10.7	13.2	13.7	14.1	12.2	7.9	7.7	4.9	8.2
1889	3.4	2.9	4.7	7.1	12.9	15.3	15.3	14.7	12.8	8.6	6.9	3.3	9.0
1890	5.7	3.1	6.2	7.1	11.7	13.5	14.5	14.1	14.6	9.4	5.7	-0.8	8.7
1891	1.3	3.9	3.8	6.2	9.5	14.7	15.1	14.1	14.2	9.4	5.6	4.1	8.5
1892	2.3	3.6	2.7	7.3	11.6	13.4	14.3	15.2	12.4	7.1	6.4	1.8	8.2
1893	2.2	4.7	7.2	10.3	13.1	15.6	16.4	17.4	12.9	9.9	5.2	4.8	9.9
1894	3.4	5.1	6.7	9.7	9.2	13.5	15.9	14.2	11.6	9.3	7.9	5.1	9.3
1895	0.2	-1.8	5.1	8.2	12.4	14.8	15.2	15.8	15.4	7.1	7.5	3.9	8.7
1896	4.8	4.6	6.7	9.1	11.9	16.2	16.2	14.3	13.1	6.9	4.3	3.9	9.3
1897	1.6	5.8	6.5	7.1	10.0	15.1	16.5	16.2	12.1	9.9	7.6	4.7	9.4
1898	6.6	5.8	4.3	8.5	10.2	13.6	15.3	16.5	15.2	11.3	7.2	7.3	10.1
1899	4.9	5.1	5.1	7.8	9.9	15.7	17.3	17.8	13.2	8.8	8.5	2.2	9.7
1900	4.4	2.6	3.7	8.3	10.3	14.7	17.7	15.1	13.6	9.8	7.3	7.2	9.6
1901	3.5	2.3	4.1	8.6	11.5	13.9	18.0	15.6	13.9	9.7	4.8	3.4	9.1
1902	4.7	1.5	6.7	7.5	8.9	13.9	14.7	14.3	12.8	9.6	6.8	4.6	8.8
1903	4.2	7.1	7.1	6.4	11.1	13.0	15.3	14.3	13.1	10.5	6.4	3.3	9.3
1904	4.1	3.4	4.3	8.7	10.9	13.3	17.1	15.1	12.5	9.7	5.2	3.7	9.0
1905	3.6	5.2	6.8	7.3	10.8	14.7	17.2	14.7	12.4	7.1	4.9	4.9	9.1
1906	5.3	3.1	5.1	7.3	10.5	14.3	15.8	16.7	13.9	10.9	7.3	3.0	9.4
1907	3.6	2.8	6.3	7.6	10.5	12.4	14.1	14.3	13.6	9.8	6.5	4.6	8.8
1908	2.5	5.3	4.3	6.0	12.4	14.3	15.8	14.6	12.9	11.8	7.4	3.9	9.3
1909	3.5	2.9	3.7	8.7	11.0	11.8	14.6	15.4	11.9	10.4	4.8	3.9	8.6
1910	3.5	5.1	6.1	7.3	11.2	14.7	14.2	15.2	12.5	10.6	3.2	6.4	9.2
1911	3.8	4.8	5.2	7.5	12.9	14.5	18.2	18.2	13.9	9.3	6.1	6.2	10.1
1912	3.6	5.4	7.2	8.8	12.1	13.9	16.1	12.9	11.1	8.2	6.3	6.7	9.4
1913	4.5	4.8	6.2	8.1	11.4	14.3	14.6	15.2	14.1	10.9	8.4	5.1	9.8
1914	3.7	6.8	6.1	9.8	10.8	14.5	15.8	16.1	13.3	10.3	6.8	4.6	9.9
1915	4.1	4.3	5.2	7.9	10.8	14.4	14.6	15.3	13.4	9.1	2.8	5.3	8.9
1916	7.5	3.8	3.3	8.2	11.6	11.8	15.3	16.4	13.0	10.6	6.8	1.9	9.2
1917	1.6	0.9	3.2	5.4	12.8	15.2	16.1	15.3	14.0	7.5	7.8	2.3	8.5
1918	3.8	6.5	5.7	6.7	13.0	13.3	15.4	16.1	11.9	9.3	5.5	6.9	9.5
1919	2.9	1.9	3.6	7.1	13.5	14.3	13.9	15.7	12.7	7.4	3.3	5.5	8.5
1920	5.2	6.0	7.2	8.2	11.8	14.4	14.1	13.6	13.0	10.4	6.8	4.2	9.6
1921	7.3	4.8	7.4	8.0	11.5	14.7	18.5	15.4	14.1	12.8	4.6	6.5	10.4
1922	3.7	4.4	4.6	5.5	12.7	13.8	13.7	13.6	12.2	8.2	5.9	5.8	8.7
1923	5.6	5.6	6.5	7.6	9.2	12.5	17.5	15.2	12.5	9.7	3.3	3.8	9.0
1924	4.7	3.3	4.1	6.9	11.6	13.9	15.3	14.1	13.3	10.1	7.1	6.8	9.3
1925	5.3	5.2	4.9	7.5	11.6	15.0	16.8	15.4	11.5	10.4	3.6	2.8	9.2
1926	4.6	6.8	6.3	9.3	10.2	13.6	17.1	16.2	14.4	8.1	5.9	4.2	9.7
1927	4.6	3.9	7.3	7.9	11.2	12.6	15.9	15.7	12.5	10.5	6.2	2.1	9.3
1928	5.2	5.8	6.3	8.5	10.9	12.9	16.1	15.3	12.8	10.1	7.6	3.4	9.6
1929	1.3	0.4	6.2	6.8	11.3	13.3	16.0	15.4	15.3	9.6	6.7	5.8	9.0
1930	5.6	2.5	5.3	8.3	10.7	15.3	15.2	15.7	13.6	10.5	6.2	4.3	9.4
1931	3.2	3.9	4.2	7.7	11.4	14.4	15.3	14.4	11.5	8.8	7.8	5.3	9.0
1932	6.3	2.9	4.7	6.9	10.5	14.1	16.1	17.1	12.9	8.8	6.6	5.7	9.4
1933	2.2	4.3	7.3	8.8	12.2	15.6	17.8	17.6	14.9	10.1	5.6	1.6	9.8
1934	4.1	3.8	4.8	8.0	11.3	14.9	18.2	15.4	14.6	10.6	6.1	8.1	10.0
1935	4.5	5.8	6.6	8.2	9.9	15.1	17.1	16.6	13.6	9.5	6.9	2.8	9.7
1936	3.7	2.6	7.1	6.3	11.5	14.7	15.3	16.1	14.4	9.4	5.5	5.3	9.3
1937	5.2	5.6	3.6	9.2	12.2	14.1	16.1	16.9	13.4	10.4	5.1	3.0	9.6
1938	5.7	5.1	9.1	7.6	10.7	14.4	15.2	16.3	13.8	10.5	9.4	4.4	10.2
1939	4.2	5.6	5.8	8.8	11.4	14.2	15.5	16.4	14.2	8.2	8.7	3.2	9.7
1940	-1.4	2.6	6.0	8.7	12.5	16.4	15.1	15.6	12.8	9.6	6.9	3.8	9.1

	J	F	M	A	M	J	J	A	S	O	N	D	Year
1941	0.5	3.5	5.1	6.4	9.4	15.1	17.3	14.7	14.5	10.4	6.6	5.6	9.1
1942	0.9	0.1	5.2	9.2	11.1	14.4	15.5	16.6	13.6	10.4	4.9	6.7	9.1
1943	4.9	6.1	6.5	10.5	11.8	14.4	16.4	16.1	13.3	10.6	6.3	3.5	10.1
1944	5.8	3.6	5.2	10.2	11.4	13.5	16.5	17.0	12.5	9.3	6.2	3.6	9.6
1945	0.4	7.1	7.9	10.1	12.2	14.6	16.7	15.9	14.4	11.9	7.2	4.9	10.3
1946	2.7	5.9	5.1	9.9	10.7	13.1	16.3	14.7	14.0	9.8	8.1	3.1	9.4
1947	2.2	-1.9	3.6	8.6	13.5	15.5	17.0	18.6	14.9	10.6	7.2	5.1	9.6
1948	5.4	4.7	8.3	9.0	11.4	13.5	15.8	15.1	13.8	10.1	7.3	5.7	10.0
1949	5.5	5.7	5.1	10.0	11.2	15.3	17.4	16.8	16.3	11.7	6.6	5.8	10.6
1950	4.2	5.3	7.4	7.6	11.3	16.2	15.9	15.6	12.9	9.6	5.7	1.2	9.4
1951	3.9	3.7	4.1	6.8	10.1	14.0	16.3	14.8	14.1	9.4	8.5	5.5	9.3
1952	2.7	3.4	6.6	9.6	13.4	14.4	16.8	15.8	10.7	8.8	4.2	2.8	9.1
1953	3.3	4.3	5.6	7.3	12.6	14.4	15.5	16.2	13.8	9.7	8.5	6.9	9.8
1954	2.9	2.6	5.8	7.6	11.2	13.4	14.2	14.6	12.7	11.9	6.9	6.8	9.2
1955	2.6	1.2	3.2	9.3	9.7	13.8	17.7	18.1	14.2	9.2	7.0	5.4	9.3
1956	3.6	-0.2	6.2	6.9	11.7	13.1	15.8	13.5	14.3	9.4	6.0	5.7	8.8
1957	5.5	5.3	9.2	8.9	10.3	15.2	16.3	15.4	12.5	10.8	6.4	4.5	10.0
1958	3.4	4.7	3.7	7.4	11.1	14.1	15.9	15.8	15.1	10.8	6.4	4.7	9.4
1959	1.6	4.4	7.3	9.4	12.8	15.2	17.3	17.2	14.9	12.6	7.1	6.0	10.5
1960	3.8	4.1	6.4	8.9	12.8	16.1	15.1	15.0	13.1	10.3	7.3	3.9	9.7
1961	3.9	6.9	8.2	10.0	11.0	14.4	15.2	15.4	15.2	10.9	6.0	2.2	9.9
1962	4.3	4.4	2.8	7.7	10.3	13.7	15.1	14.5	12.6	10.4	5.5	1.8	8.6
1963	-2.1	-0.7	6.0	8.7	10.6	14.9	15.2	14.3	12.9	11.1	8.2	2.6	8.5
1964	3.4	4.5	4.3	8.7	13.3	13.8	16.1	15.5	14.1	8.9	7.4	3.6	9.4
1965	3.3	3.1	5.2	8.0	11.7	14.7	14.0	14.9	12.3	11.0	4.5	4.7	8.9
1966	2.9	5.7	6.5	7.2	11.0	15.4	15.0	14.7	13.8	10.1	5.6	5.5	9.4
1967	4.5	5.4	7.0	7.7	10.4	14.0	16.7	15.7	13.5	10.8	5.4	4.2	9.6
1968	4.4	1.9	6.3	8.1	9.8	14.8	15.0	15.4	13.9	12.5	6.5	3.0	9.3
1969	5.5	1.0	3.3	7.4	11.2	13.9	16.8	16.4	13.9	13.0	5.4	3.3	9.3
1970	3.7	2.9	3.7	6.7	13.0	16.4	15.2	16.0	14.4	10.7	7.8	4.3	9.6
1971	4.5	4.5	4.9	7.9	11.6	12.4	16.9	15.6	14.0	11.3	6.0	6.6	9.7
1972	3.9	4.3	6.5	8.2	10.5	11.8	15.6	15.1	11.7	10.6	6.3	5.8	9.2
1973	4.5	4.3	6.2	7.0	11.4	14.8	15.6	16.5	14.3	9.0	6.0	4.9	9.5

For comparison: Means for the 30-year standard period 1931-1960 are:

3.4	3.9	5.9	8.4	11.4	14.6	16.2	16.0	13.7	10.1	6.7	4.7	9.6
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Extreme values for each month and dates

Highest	1916	1779	1957	1865	1833	1846	1783	1947	1729	1969	1818	1934	1949
	7.5	7.9	9.2	10.6	15.1	18.2	18.8	18.6	16.6	13.0	9.5	8.1	10.6
Lowest	1795	1947	(1674)	1837	(1698)	1909	(1695)	1912	(1694)	1740	1782	1890	1740
			1785		1740	1916	1816		1807				
	-3.1	-1.9	1.2	4.7	8.6	11.8	13.4	12.9	10.5	5.3	2.3	-0.8	6.8

5. DERIVATION FOR 'CENTRAL ENGLAND' BEFORE 1723: NEW MATERIAL, AND RESULTS OF REVISION

For the years 1708-1722 we now have an additional North of England non-instrumental diary. This has come to light in MS in a collection of papers recently deposited in the Sheffield City Library. The writer, William Elmsall (1665-1740), was Under-Steward to the Manor of Wakefield. He lived at Thornhill and kept a brief daily note of his activities with very few omissions from January 1708 to November 1740; to each entry he added a symbolic representation, devised by himself, of the course of the day's weather, with wind direction and an indication of strength. The weather is not quite specific to one place, as he was remarkably active, riding on many days about his legal and other business through-

out much of the West Riding between Wakefield and the moors to the west; occasionally he journeyed farther. His ingenious symbolic representations can be solved by comparing them with the weather recorded on the same day by Oates at Chesterfield, Nettleton at Halifax and Short at Sheffield (MS sources at the end of the paper). It becomes evident, for example, that he distinguished continuous rain from showers, and was only moderately alert in regard to sleet and snow, fairly good on thunder. The great value of this diary is that it provides daily wind direction and strength well to the north of London, and hence a better indication of the probable pressure pattern and developments. One can, for example, deduce the likelihood of a persistent northerly blocking pattern in July 1719, giving great heat (not unlike August 1947 or July 1955); it is supported by the brief note in Blundell's diary, kept near Liverpool (1702-1728; source at the end of the paper). The indication of the character and duration of each days rainfall is useful; on snowfall, Elmsall's keenness of observation is not up to that shown in the (Rawlinson 1161 D) anonymous MS. that I found in the Bodleian, and about which I am now inclined to think, from the writing, that it was written up in London, west of the City by Christopher Rawlinson himself during 1699 to 1717; what proportion of the daily observations may have been made by himself I am as yet unable to establish. Rawlinson's entries end in November 1717, after which until November 1722 we must do what we can for the London area with the well-known but less detailed journal kept by Smith at Richmond (MS. copy, Royal Meteorological Society's library). Instrumental readings for 1716-1722, lately found, are under scrutiny.

Elmsall's West Riding journal not only covers these years, but the frequency with which he notes the occurrence of 'frost' (annual average of 56 days) can be tabulated and compared with the present day (air frost at Wakefield, 59 days). Some of the entries can be disputed; but as a whole there is a very fair relationship with the mean temperature of the winter months.

It is also useful to have a supplementary record, covering 32 years, of the frequency of days with snow or sleet recorded as falling; this provides a further check on the overall temperature of the winter six months, November-April. Hence I have made some small changes in a few of the previous estimated monthly means over this period.

For the years 1699-1706, during which Derham provided thrice-daily readings of a thermometer suspended out-of-doors on a north-facing wall at Upminster, 15 miles east of the city, I made some further revision of the monthly means previously published. He was the first English observer that we know of who kept his instrument outside in the shade, rather than beside a window or in a cool indoor passage; but he gives no details. I proceeded to calculate the average difference for each month between his early morning, noon and evening readings, comparing them with those derived for the same hours from the old Glaisher Stand at Greenwich. These were published (Glaisher 1848); understandably they are considerably larger than the corresponding figures deriving from the North Wall screen at Kew (British Magnetic and Meteorological Yearbook, 1916) or for Glasgow Observatory (Becker 1925). At the same time, Derham's description of his thermometer made by Patrick and its graduation in inches does not lead to over-confidence in its accuracy (Derham 1702). Nevertheless, to quote one example, the mean interval between the 05 hr and noon readings in July at Upminster was fully as great as that on the old Glaisher Stand at Greenwich; hence it appeared that Derham's exposure was somewhat more sheltered and likely to be subject to radiation from adjacent objects than I had previously thought, with the result that my previously published values were revised a little upward, particularly in the summer months.

Derham is known to have continued to measure rainfall until at least 1716, and he quotes a few thermometer readings in the severe winter of 1709; hence there may yet be found some MS. for the missing years. Search of the archives of the Royal Society, and of

the Sloane Collection and others in the British Museum, has not brought any more to light. Indeed, we appear to owe it to Sloane's collecting propensities that a number of the earliest meteorological journals kept in London have survived at all (e.g. Downes 1680-1694, Conyers 1673-1680); it is on record that some of those at the Royal Society were discarded as 'of no further use' (*Symons Meteorological Magazine*, 1924, pp. 183-184).

The reduction of a series of approximate outdoor monthly means, from a consideration of these earliest meteorological journals using crudely made and clumsy thermometers indoors has been described elsewhere (Manley 1961, 1963); it is only the fascination of the chase that takes one into the nightmare assemblage of daily observations with which Conyers, for example, filled his little notebooks between 1673 and 1680. We do have, nevertheless, the very consistent diary, giving a continuous sequence of non-instrumental observations through the whole period (November 1668-December 1700) that was kept in Westminster by John Gadbury; and there are several others, e.g. by Elias Ashmole (Lambeth 1677-1685) and John Locke (1666-1667 at Oxford, thereafter several fragments, e.g. in 1682; and continued by him at Oates, near Ongar, through most of the months 1692-1703). All these are in the Bodleian MS.; Robert Hooke's MS. daily observations over 13 months in 1672-1673 are in the Guildhall Library.

Outside London we have very little. Christopher Sanderson, of Eggleston in Teesdale, has a valuable if somewhat broken sequence of daily non-instrumental observations, 1682-1689 (MS., Gateshead Library) and Sir Philip Skippon's journal, from Wrentham in Suffolk, includes barometer and thermometer readings through most of 1673 to 1674 (Margary 1927). Richard Towneley is known to have kept daily observations near Burnley in Lancashire, but I have not succeeded in finding them. They are, however, mentioned here in the hope that others in time may succeed. At present, any estimate for 'central England' before 1708 must still depend largely, if not entirely, on extrapolation from the monthly means deduced for the London area; these in turn are manifestly subject to a variety of sources of error, although in regard to the winter half-year they receive some general control through comparison of the decadal means of the frequency of days with snow.

Nevertheless, in the present state of knowledge, all monthly means are rounded to 0.5 deg C (nearly 1 deg F) before 1700; greater precision of statement would give a false impression.

It may be mentioned here that for the very severe winter (December-February) of 1683-1684, which appears to be the coldest for which we have instrumental readings, we have a sufficiency of daily notes of wind and weather from Teesdale and from Oxford to make a tolerable meteorological interpretation. Support for the statement that it ranks as the most severe, in respect of temperature, in 300 years is forthcoming from reports such as that the ground was frozen 27 inches deep near Manchester; that the Queensferry near Edinburgh was almost stopped, that the Flanders coast was obstructed by ice for a fortnight; that there was ice on the sea for two miles off Deal, three miles off Dymchurch; and that 'large trees were split by the frost' in Enfield Chase. Among the sources of more general comments on the northern counties we may cite the Rector's Book of Clayworth, Notts. (1672-1701) published in 1910 and noted by C. E. P. Brooks, and John Ryle's MS. journal from Northenden near Manchester (1656-1689).

6. FLUCTUATIONS BEFORE 1670

To the assemblage of monthly means given below, that takes us back to the fragment that we have of Robert Hooke's daily observations (April 1672-May 1673), I have ventured to add a further series of estimates from 1659 onward. These depend largely on consider-

ation of the probable air masses involved. The only sequence of thermometer readings that we yet have is that by John Locke while he was interested in medicine at Oxford (March 1666–April 1667). Non-instrumental daily entries include Gadbury, November 1668 onward; a fairly complete MS. from Stockwell (British Museum Sloane Collection), September 1666–October 1667; and, between 1652 and 1683, a number of short sequences of daily observations, rarely more than 20 days in length, that were published by John Goad in his *Astrometeorologica* (1686) a fairly well-known work of which there is a copy in the Royal Meteorological Society's library. From 1660 onward the great majority refer to London; before that, to Yarranton north of Oxford. They are part of his effort to associate particular types of weather with astronomical configurations, but they are so much interrupted that, in general, little can be made of them; it is particularly disappointing not to be able to make much of the very severe winter of 1658, for which there are practically no entries between January and June.

Goad evidently had access to a well-kept daily record, hence the original may yet turn up in some out-of-the-way library. We know that such records existed; for example, Thomas Short (in his 1749 'Natural Chronology') knew of and quoted from a forty-year record kept by T. Say; we hear of a 15 years daily record kept by an almanac-publisher, Baker, about 1669; and of another by John Beal who in the 1660s was known at the Royal Society for his writings on Herefordshire orchards, and later became Rector of Yeovil.

There are also the rather thin but useful descriptive notes in a weather journal kept by the Reverend Samuel Clarke (1658–1686) from Raynham in North Norfolk; the MS. is in the Norwich City Library and I have to thank Dr. Schove for calling my attention to it some years ago. Another series of descriptive notes is provided by the Reverend R. Josselin's journal (1644–1681) now available in transcript in the Essex County archives at Chelmsford. From his rectory at Earls Colne he gives notes of some value for the months and seasons, and sometimes names particular dates, but the calendar problem is not easily overcome. A little can be added from a journal at Clopton (1648–1650), from Sir Thomas Mildmay's Essex Journal (1633–1651); this almost takes us back to the interrupted series of weather notes, 1598–1635, by Dr. Napier from Great Linford in Buckinghamshire, cited by J. N. L. Baker in his paper on seventeenth century weather in this Journal (1932). There are scattered references in many other diaries and journals, but they are too few to make much of through the Civil War. I have searched with little success through the many volumes published by our North Country historical societies. One seeks in vain for much one would like to know, for example, in the brief comments on life in upland Derbyshire by Adam Eyre (1647–1650) or in the Oglander papers from the Isle of Wight (sources below).

It would indeed be gratifying if some estimate, even of the temperature of the seasons rather than the individual months, could be provided for a further hundred years, back to the onset, about 1560, of those groups of less favourable seasons with which Professor Lamb and Professor Flohn are concerned as a likely precursor of the noteworthy advance of the alpine glaciers. As yet, however, the English and Scottish documentary material is insufficiently detailed to enable the attempt to be made. For the present we must content ourselves with the deductions that appear to be justified from the course of events in neighbouring Europe; here, the assemblage of material with regard to floods, storms and ice on west European rivers by Weikinn (1958–1967) is useful. For example, the periods of marked glacier advance in the western Alps that we know of, after 1700, accompany or quickly follow those in which the spring (March–May) mean temperature, over a decade, in central England falls below 8.2 or 8.1°C, say 46.6 to 46.8°F. Likewise, from 1670 onward there is a fair accordance between the fluctuations of the date of the beginning of the vintage in Northern France and the mean spring–summer temperature, March–August, in England

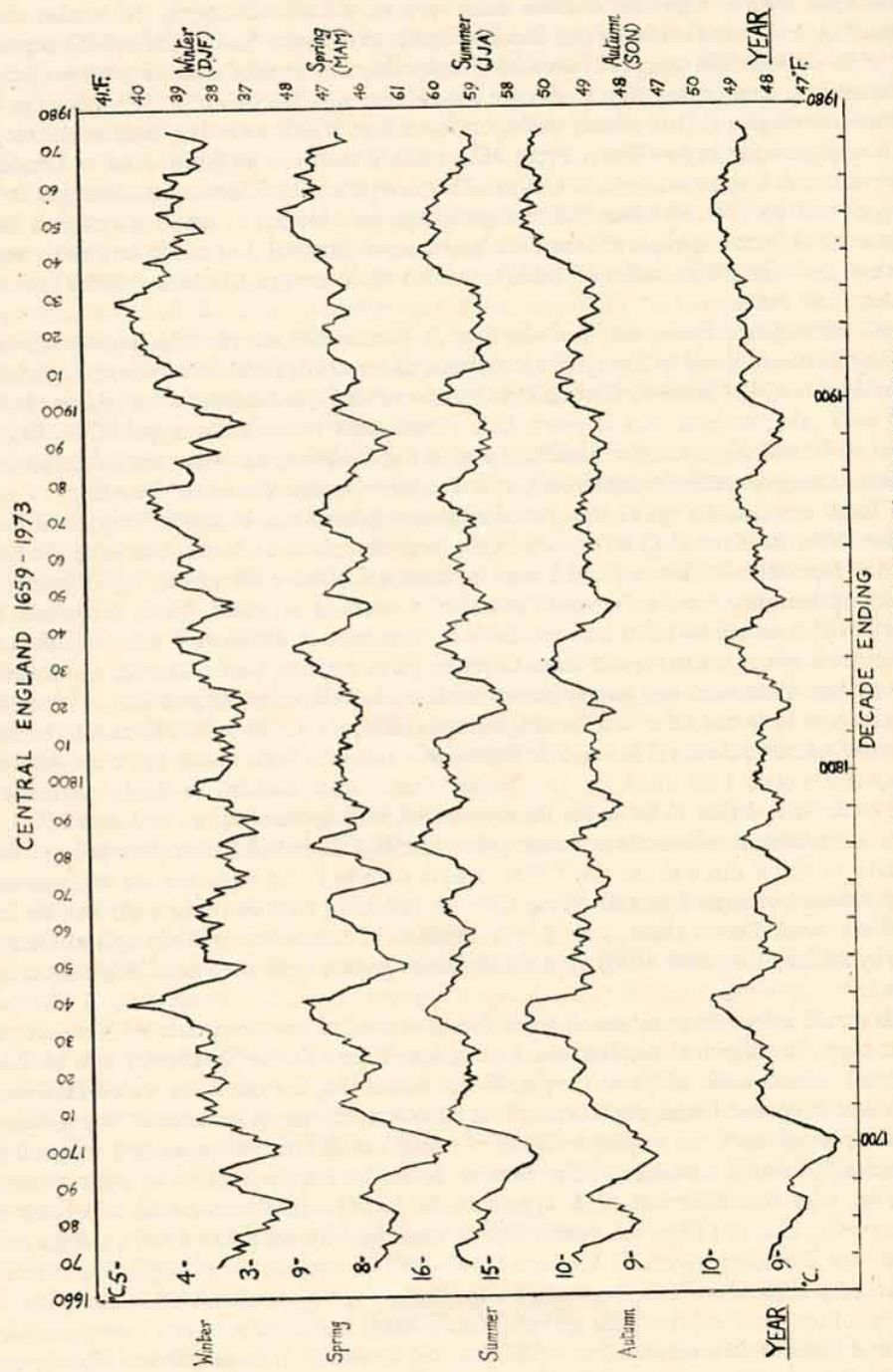


Figure 1. Decadal running averages of seasonal and annual mean temperatures.

(Ladurie 1972); hence we can give estimates for our own decadal spring-summer temperatures based on the French vintage dates, back to sometime before 1500. It is more difficult to decide on the variability of the winter mean temperatures (December-February); we have accounts of some of the severe winters such as 1608 in fair detail, but very little with which to estimate the average temperature characteristic of what were then regarded as mild winters. Moreover, it is in the winters that we need more detail of what was happening farther north. In the winter of 1709, for example, which was quite outstandingly severe at Paris, the extremes were less marked at London; for example, the river was not frozen for so long as in 1684; and in Scotland it was remarked that in 1709 neither the major rivers nor the lakes were frozen, by contrast with events in southern England and France.

For the present, we must be content to cover the climate of the period 1560-1660 in very general terms, making use of the well-known continental tabulations (Easton 1928, Vanderlinden 1924), the sixteenth and seventeenth century continental meteorological journals cited by von Rudloff (1967), the few Scottish comments, the Fugger news letters (edition 1924), together with our own chroniclers (T. H. Baker 1883, Short 1749). We can then search our diarists, and the scattered entries from miscellaneous sources listed below (e.g. the Liverpool Town Books, the local histories, the many scattered comments on harvests); and link them with the vintage dates and glacier behaviour already noted. It seems possible that in time more information might be forthcoming from the study of peat-bogs and lake sediments. Lichenometry, tree-ring studies and other objective methods may likewise hold possibilities. We need to know more, a matter that became clear at the Aspen Climatological Meeting in 1962, about the onset and progress of what some have been inclined to call, not very satisfactorily, the Little Ice Age, and the remarkable vicissitudes that appear to have been characteristic of the seventeenth century. This paper, it is hoped, may serve to stimulate others to seek new methods.

With regard to the reliability of the earlier part of the Table, built up as it is largely by the exercise of judgment on series of observations that are formidably open to doubt, we can say that back to 1700 there is a very comforting accord with other western European series and, beyond that, there is overall support from analysis of the frequency of days with snow, and with contemporary descriptions of the seasons.

I have to acknowledge the generous assistance of a number of our city and country archivists in the search for possible documentary material and for access. For the opportunity to visit many collections, ranging from the libraries in Exeter and Bath to those in Perth and Inverness. I am indebted to the Shell Organization for a personal research grant to cover investigations of our long-term records, more particularly in regard to fluctuations of upland rainfall and snowfall. I have again to thank the Officers of the British Museum, the Royal Society, the Bodleian Library, the John Rylands Library, the Guildhall Library and Lancing College for privileges of access to their MSS.

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Napier MS., (Bucks.) 1598-1635
Locke MSS., (Oxford) 1666-1667 (Ongar) 1692-1703, and fragments; instrumental
Gadbury MS., (London) 1669-1701 (Rawlinson Collection, 662D); daily
Anon. MS., (Middlesex) 1699-1717 (Rawlinson Collection, 1161D); daily
Ashmole MS., (London) 1677-1685; daily
British Museum (mainly Sloane Collection)
Conyers MS., (notebooks) (London) 1673-1677, 1678-1680; difficult, instrumenta
Downes MS., (London) 1680-1694; difficult, instrumental
Stukeley MS., (London) 1722-1724; instrumental
Short MS., (Sheffield) 1727-1756; interrupted, instrumental
Anon. (London; Stockwell) 1666-1667; 10 months, descriptive, most days
Beighton MS., (Midlands) 1707-1708, 1737-1739; part instrumental (Beighton also contributed notes to the Ladies Diary, 1715-1724)
Mildmay MS., (Journal) 1633-1651 (Essex)
Guildhall Library, London
Hooke MS., journal (much of 1671-1672); observations daily, instrumental
Wallington MS., journal (1623-1646); very little use
Royal Society's Library (Papers and Letters Collections)
Derham MS., (Upminster) 1700-1706; instrumental, daily
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