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Harmonic Analysis of Hourly Observations of Air Temperature and Pressure at British Observatories. Part I. Temperature

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XII. *Harmonic Analysis of Hourly Observations of Air Temperature and Pressure at British Observatories.*—Part I. *Temperature.*

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[PLATES 19–23.]

THE Meteorological Council have lately published a volume entitled 'Harmonic Analysis of Hourly Observations of Air Temperature and Pressure at British Observatories.' It was thought preferable that this publication should be limited to the series of Tables giving the computed values of the harmonic constants, with a brief introduction explaining how the calculations had been carried out, and that the discussion of the results should be embodied in a separate memoir, which I hoped to communicate to the Royal Society, an intention which I now realize.

I have annexed to the present communication a selection of such of the Tables given in the volume referred to as appear necessary for my present purpose, and I have added a series of graphical representations of some of the results of the computations, which will facilitate the study of the subject.

I have also thought it convenient to reproduce, with some few modifications, the explanations, contained in the introduction of the same volume, of the method according to which the computations it contains were made.

The series of Tables to which I have referred give the results of computations commenced by myself, and completed in the Meteorological Office under the supervision of Mr. R. CURTIS.

The computations, as originally undertaken, were designed to supply the harmonic analysis of the hourly observations of temperature and pressure made at Greenwich Observatory, in each case for twenty years, which were published in 1878.

Subsequently it was determined to extend the investigation, as a part of the regular routine of the Meteorological Office, so as to obtain the harmonic constants from the photographic records of temperature and pressure of the self-recording instruments at the seven observatories maintained by the Meteorological Office, viz., Valencia, Armagh, Falmouth, Glasgow, Stonyhurst, Aberdeen, and Kew, for a series of twelve years.

With a view to reducing the necessary labour, the computations of the harmonic components, extending to the fourth order, have been made from the Greenwich data by the method proposed by myself (and explained in the 'Proceedings of the Royal Society,' vol. 42, pp. 61–79), with the help of the Tables to be found in the Appendix to the "Hourly Readings of the Self-recording Instruments at the Observatories of the Meteorological Council" for 1884.

The values of the constants for the seven observatories of the Meteorological Office, extending to the third order, were obtained from the photographic records by means of the mechanical analyser designed by Sir W. THOMSON, a description of which will be found in the 'Proceedings of the Royal Society,' vol. 27, p. 371, and as to the use of which and the degree of dependence to be placed on its indications reference may be made to the 'Annual Reports of the Meteorological Office,' for the years 1881, 1883, 1885, and 1890, and to the 'Proceedings of the Royal Society,' vol. 40, p. 382.

In these Tables, following the usual formula expressing the hourly value A_n in terms of its harmonic components,

$$A_n = p_0 + p_1 \cos n\, 15^\circ + q_1 \sin n\, 15^\circ + p_2 \cos 2n\, 15^\circ, \text{ \&c.},$$

p_0 represents the mean value for the whole twenty-four hours; the coefficients of the cosines are designated by the letters p_1, p_2, p_3, &c., for the several orders of components; and those of the sines by the letter q_1, q_2, q_3, &c. The values are expressed in degrees Fahrenheit for temperature, and in inches for pressure.

The total amplitudes of the several components in the corresponding formula, involving sines only, are designated by the letter P_1, P_2, &c., where $P_1 = \sqrt{(p_1^2 + q_1^2)}$, and

$$A_n = p_0 + P_1 \sin (n.15^\circ + T_1) + P_2 \sin (2n.15^\circ + T_2) + P_3 \sin (3n.15^\circ + T_3), \text{ \&c.}$$

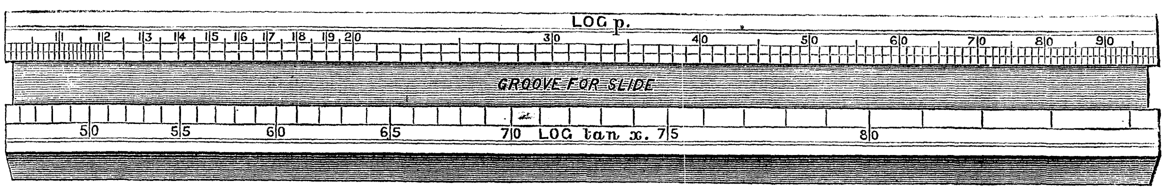
The Tables, however, instead of giving the values of the subsidiary angles T, show the epochs of the first maximum reckoned from midnight in angular measure, the letters μ_1, μ_2, μ_3, &c., indicating the epochs for the several components. This method of stating the phase or epoch of the components has the advantage of directly indicating their relation to the hour of the day, and, therefore, to the position of the Sun, to which the diurnal variations of temperature and pressure should obviously be referred.

If it be understood that $\tan x = p/q$, disregarding the signs of the coefficients, then the quadrants in which T will fall when regard is had to the signs of p and q, and the relation of μ to T and x, for the several components, are shown in the following Table.

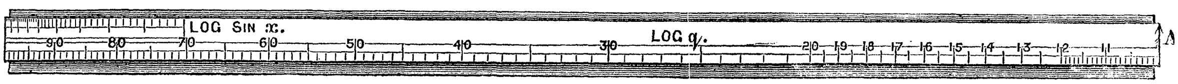
	$p+, q+$.	$p-, q+$.	$p-, q-$,	$p+, q-$.
Value of T	x 0 to 90°	$360° - x$ 270° to 360°	$180° + x$ 180° to 270°	$180° - x$ 90° to 180°
Value of μ_1 . . .	$90° - T_1$ $90° - x$	$450° - T_1$ $90° + x$	$450° - T_1$ $270° - x$	$450° - T_1$ $270° + x$
Value of μ_2 . . .	$45° - \frac{1}{2}T_2$ $45° - \frac{1}{2}x$	$225° - \frac{1}{2}T_2$ $45° + \frac{1}{2}x$	$225° - \frac{1}{2}T_2$ $135° - \frac{1}{2}x$	$225° - \frac{1}{2}T_2$ $135° + \frac{1}{2}x$
Value of μ_3 . . .	$30° - \frac{1}{3}T_3$ $30° - \frac{1}{3}x$	$150° - \frac{1}{3}T_3$ $30° + \frac{1}{3}x$	$150° - \frac{1}{3}T_3$ $90° - \frac{1}{3}x$	$150° - \frac{1}{3}T_3$ $90° + \frac{1}{3}x$
Value of μ_4 . . .	$22\frac{1}{2}° - \frac{1}{4}T_4$ $22\frac{1}{2}° - \frac{1}{4}x$	$112\frac{1}{2}° - \frac{1}{4}T_4$ $22\frac{1}{2}° + \frac{1}{4}x$	$112\frac{1}{2}° - \frac{1}{4}T_4$ $67\frac{1}{2}° - \frac{1}{4}x$	$112\frac{1}{2}° - \frac{1}{4}T_4$ $67\frac{1}{2}° + \frac{1}{4}x$

The values of P and μ were throughout obtained from the calculated values of p, q, by means of a slide rule arranged for the solution of the equations, $\tan x = p/q$, and $P = p/\sin x$, as shown below :—

Fixed Rule.



Slide.



The upper scale of the *fixed* rule is graduated to show logarithms of numbers, and serves to indicate the value of log p. The graduations of the lower scale of the same rule represent log tangents to radius equal 1 on the upper scale and indicate log tan x.

The graduations of the lower edge of the *slide* rule are logarithms of numbers in the reverse order to those of the *fixed* rule, and indicate the values of log q. The upper edge of the *slide* rule is graduated to show log sines to the same radius as before, and indicates the value of log sin x.

The rule is used as follows :—The *slide* is moved in the groove till the zero point A, on its top edge, comes opposite to the graduation corresponding to log p on the *fixed* rule. Then opposite the graduation corresponding to log q on the lower edge of the *slide* will be found, on the scale of log tangents, the value of the angle x, or $\log \tan x = \log p - \log q$.

Then, without moving the slide, the value of P will be found on the scale, showing $\log p$, opposite the graduation on the *upper* edge of the slide corresponding to $\log \sin x$; or $\log \mathrm{P} = \log p - \log \sin x$.

The first series of Tables in the volume spoken of deal with Greenwich air temperature, the next refer to Greenwich pressure. Then follow the results obtained by the mechanical analyser for the seven observatories, first those dealing with temperature, and next those for pressure.

The Tables for each series (a few of which only are reproduced with this paper) are arranged as follows :—

No. I. gives the values of the p, q coefficients, in the case of Greenwich, for the first four orders for each year and for each month, and for the seven observatories of the Meteorological Office for the first three orders. The mean values, in the case of Greenwich, for each series of five years, as well as the means for the whole 20 years, are also given; and for the seven observatories for the period of 12 years.

No. II. is deduced from No. I., and gives in like form the values of P and μ for the four, or three components (as the case may be) for each year and month, and the corresponding means.

It will be observed that, in a few cases, μ has a negative sign, which implies, as will be further explained, that the epoch of maximum is thrown back *before* midnight.

No. III. is derived from No. I., and gives the mean annual values of the p, q coefficients for each year, with the five-year and 20-year means as before.

No. IV. is also derived from No. I., and gives the means of the several monthly values of the p and q coefficients for the 20 years. Table A, annexed to the present paper (p. 639), reproduces the results for the Greenwich observations, and Table C those for the seven observatories.

No. V. is derived from No. II., and gives the mean annual values of P and μ for each year, with the five-year and 20-year means.

No. VI. is also derived from No. II., and gives the means of the several monthly values of P and μ for the 20 years.

No. VII. brings together the monthly mean values of P and μ for the first four orders of components, for the four five-year periods over which the observations extend; the phase of maximum being in this Table stated in *apparent* time, instead of in *mean* time, as is done in the others. Table B, which is annexed to this paper, gives these results for the Greenwich observations, and Table D those for the seven observatories.

No. VIII. shows the mean monthly values of P and μ, obtained from the mean hourly values for each month and the entire year for the whole series of 20 years, as given in No. IX. These values will be seen to differ from those supplied by No. VI., and would be the values of P and μ, deduced from the mean values of p, q given in No. IV. The differences are due to No. VI. giving the means of the whole of the *separate* values obtained from the observations of the separate years and months, while the results in No. VIII. are obtained from the mean of the hourly values for the whole period in the aggregate, in which the effects of some of the fluctuations are necessarily lost. For the same reason, the mean value for the year, in No. VIII., is not the arithmetical mean of the 12-monthly values.

No. IX. gives the mean hourly values for each month of the year, obtained from the Greenwich hourly observations. This Table is extracted from the volume of Greenwich meteorological observations for 20 years.

No. X. gives the corrections that should be applied to the Greenwich observations on account of the non-periodical variation between the initial and final midnights of the daily period. The nature of this correction, and how the non-periodical variation affects the computations of the harmonic constants, are explained in the papers before referred to; (Proceedings of the Royal Society, vol. 42).

No. XI. gives the mean value for each hour and for each year, corrected as above, and the mean for the whole 20 years.

The Tables VIII. to XI. could not be prepared in the case of the seven observatories of the Meteorological Office, inasmuch as the numerical mean values of the hourly readings had not been obtained when the calculations now published were carried out.

The 20-years series for Greenwich temperature extends from 1849 to 1868, and that for pressure from 1854 to 1873, so that the results will only be strictly comparable for the 15 years from 1854 to 1868. The five-year means compared with those for the whole series of years serve to indicate how far the mean results, obtained from relatively short periods, are likely to deviate from those got for long periods. These computations also show the degree of consistency of the computed values of the quantities dealt with, from year to year, and from month to month, in a considerable series of years.

It is necessary to state that there has occasionally been some difficulty and uncertainty attending the calculation of the mean values.

In the first place, in the series of values of the p, q coefficients, if the signs change periodically, as will be seen to be the case in the third and fourth orders, the arithmetical mean can give no true indication of the mean extent of the variations that have actually taken place. For instance, if the positive and negative quantities are in the aggregate nearly equal, the mean result would be nearly zero, though, in fact, the variations may have been very marked, and the positive and negative sums considerable.

Again, as the several components of the diurnal curve of orders above the first are recurrent, there is in some cases an ambiguity arising from the difficulty of determining whether a change of phase in successive months takes place by occurring later or earlier. This, no doubt, is mainly due to the monthly periods, for which the means are computed, being too great to admit of following the several steps of a rapid change, such as takes place about the equinoxes in the components of the third and fourth orders. A somewhat similar difficulty arises at times in the case of what may be termed casual irregularities in the position of the phase of maximum, in dealing with some of which it becomes uncertain whether the maximum has been thrown forward or backward.

In dealing with the series of Greenwich temperature values, a doubt of this sort arises in relation to the abrupt changes in the value of μ_4 between January and February, and again between October and November, which might be attributed either to retrogression of the phase of maximum, or to progression. The uncertainty, however, in such a case hardly affects the mean monthly values, which are fairly consistent; but a doubt is introduced in determining an annual mean, the numerical value of which will depend on the conclusion adopted as to the way in which the changes take place. This hesitation is unavoidable in the absence of a series of values calculated for short periods while the change is going on.

Much greater uncertainty prevails in dealing with the barometric values than with the thermometric, the irregularities in the former being far more numerous and perplexing.

It may be noticed with reference to the quantities p, q, that their absolute amounts represent the extent of the *amplitudes* of the components, while their *signs* only indicate the phase, or epoch of maximum, in relation to the successive quadrants in each recurring series of components. A succession of signs in the order $+p$, $+q$; $-p$, $+q$; $-p$, $-q$; $+p$, $-q$, corresponds to an epoch of maximum gradually becoming later, and *vice versâ*. The mutual destruction of a series of positive and negative values of p, q will, therefore, merely signify that there is no true time of maximum, or that all positions are equally probable or uncertain.

When, as is not seldom the case, there are considerable variations in the values of μ, an assumption may become necessary, in computing the mean of these values, as to the direction in which the departure of the separate values from the mean should be reckoned, whether onward or backward.

For instance, in the Greenwich tables for temperature, the value of μ_2 in the month of May for the year 1885 would by the computation appear as 85° 1′. Inasmuch, however, as will be seen from the separate values, the mean value is evidently much nearer to the commencement of the first quadrant, to which μ_2 appertains, than to its termination, it has been assumed that the value instead of being 85° 1′ should be represented by − 4° 59′; that is to say, that the departure of the maximum from the mean has taken place by occurring *earlier* and not *later*. All the entries of μ in the Tables marked with the minus sign indicate that an assumption of this description has been made.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Part I.—Temperature.

Greenwich Temperature.

The series of Tables dealing with Greenwich temperature shows that, with considerable variations in the absolute values of all the p, q coefficients for the several months, and from year to year, as well as of the total amplitudes P, and the epochs of maximum μ, there is still a strongly marked general consistency in the characteristics of the various elements. Reference to Table B annexed to this paper (which is Table VII. of the Greenwich series above described) shows very clearly that, with relatively few exceptions, chiefly to be found in the winter months, and among those components the absolute values of which are very small, the mean monthly epochs of maximum in the several five-year periods differ among one another by very small amounts, corresponding to intervals of time seldom as large as half-an-hour. As, however, the weight of the conclusions that may be drawn from these computations depends greatly on the internal evidence supplied by their greater or less consistency among themselves, it is important to dwell somewhat more on this point.

The requisite test will best be supplied by the values of μ which indicate the times of maximum phase, and are, therefore, immediately dependent on the Sun's action, and should follow his position; and this being subject to regular periodical change in the course of the year, it would follow that if the values of μ show corresponding regular, or nearly regular, periodical variations, they may be regarded as affording valid internal evidence of being trustworthy. The values of P, the total amplitude or variation of temperature, which are certainly subject to influences of a much more local and irregular character, will be liable to much greater and more irregular changes.

A convenient and succinct summary of the facts bearing on this point will be found in the following Table, which shows for the series of 20 years the number of times (reckoned as a percentage) in which the computed values of μ for single months fall in the several quadrants, the hours corresponding to which are as follows :—

Time of Maximum according to Value of μ falling in successive Quadrants.

Components.	1st quadrant.	2nd quadrant.	3rd quadrant.	4th quadrant.
First . . .	Midnight to 6 A.M.	6 A.M. to noon	Noon to 6 P.M.	6 P.M. to midnight
Second . .	,, ,, 3 ,,	3 ,, 6 A.M.	6 A.M. to 9 A.M.	9 A.M. to noon
Third . . .	,, ,, 2 ,,	2 ,, 4 ,,	4 ,, 6 ,,	6 ,, 8 A.M.
Fourth . .	,, ,, 1.30 ,,	1.30 ,, 3 ,,	3 ,, 4.30 ,,	4.30 ,, 6 ,,

TABLE showing frequency of the Value of μ falling in the several Quadrants in different Months of the Year.

Month.	1st component.	2nd component.		3rd component.				4th component.				
	Quadrant.	Quadrant.		Quadrant.				Quadrant.				
	3	4	1	4	1	2	3	4	1	2	3	4
January	100	..	100	..	..	..	100	15	60	25		
February	100	..	100	..	..	..	100	25	5	..	70	
March	100	..	100	5	20	75	..	..	..	..	95	5
April	100	5	95	..	100	..	..	..	..	20	70	10
May	100	35	65	..	100	..	..	5	45	50		
June	100	45	55	..	100	..	..	..	100			
July	100	10	90	..	100	..	..	5	35	60		
August	100	..	100	..	100	..	..	..	..	55	45	
September . . .	100	..	100	..	84	16	..	..	..	5	95	
October	100	..	100	..	..	40	60	..	..	10	85	5
November	100	..	100	..	..	..	100	25	40	25	10	
December	100	..	100	..	..	..	100	15	75	10		

NOTE.—Where the 4th quadrant is shown as preceding the 1st quadrant, it is assumed that the phase has fallen back, or occurred earlier.

These figures show that in their main features the variations in the value of μ for the second, third, and fourth components have a truly periodical character, and that as the year passes from winter to summer the maximum phase of the second and third travels backwards, that is, gradually occurs earlier in the day, while it returns in the opposite direction, becoming gradually later, in the change from summer to winter. In the fourth component corresponding changes take place between the equinoxes and the solstices.

A reference to Table B from the Greenwich series will show in more detail how well the consistency of the results is maintained in all the components.

The first component μ_1 is always in the first quadrant, *i.e.*, between noon and 6 P.M. The variation of the five-years mean from the 20-years mean is in no month more than $2\frac{1}{2}°$, or 10 minutes of time, and the average for all the months is less than half that amount.

In the second component the retrogression of the phase of maximum in the summer months leads to μ_2 (which from August onwards to March is always in the first quadrant, or between midnight and 3 A.M.) falling back into the fourth quadrant, that is occurring before midnight, and the greater frequency of this in May and June is therefore quite consistent with the regular periodical change which brings the mean value of μ_2 in June very nearly to zero, or midnight. The variation of the five-years mean from the 20-years mean is in no month greater than 6° or 24 minutes of time, and for the whole year the average variation is only $2°{\cdot}3$, or 9 minutes of time.

In the third component, from April to August, μ_3 is always in the first quadrant, or between midnight and 2 A.M. In September and October it changes rapidly to the third quadrant, in the last of these months 40 per cent. of the values being found in the second quadrant, and in November the value is established in the third quadrant, that is between 4 A.M. and 6 A.M., and there it remains till the end of February. In March μ_3 falls back to the first quadrant, 75 per cent. of the values being in the second quadrant and the rest in the first quadrant, with the exception of a single case which falls back to the fourth quadrant, or before midnight. The variation in any month of the five-years mean from the mean of 20 years in no case exceeds 5°, or 20 minutes of time, and the mean variation for all months is 2°·1, or $8\frac{1}{2}$ minutes.

The fourth component shows double maxima and minima values of μ_4, the former occurring at the two equinoxes, the latter at the two solstices. In the winter months, November to January, the greatest frequency is in the first quadrant, between midnight and 1.30 A.M., with a considerable number before midnight or in the fourth quadrant, and a few in the second quadrant, or after 1.30 A.M. Again in May, June, and July the values of μ_4 are chiefly in the first and second quadrants, with a few cases in the fourth quadrant, while the values in June invariably fall in the first quadrant. From February to April, and again from August to October, the greatest frequency of μ_4 is in the third quadrant, or between 3 A.M. and 4.30 A.M., with deviations in the one direction to the second quadrant, and in the other to the fourth quadrant. In March and September 95 per cent. of the values fall in the third quadrant; February and April on the one side, and August and October on the other, being months of transition, between the equinoctial maxima and solstitial minima. The largest variation of the five-years mean from that for 20 years, for any month, is 10°, or 40 minutes of time, and the average for all months 4°·3, or 17 minutes. The absolute values of the p_4, q_4 coefficients being very small, the maximum being less than $\frac{1}{4}$°, and the average being less than $\frac{1}{10}$th degree Fahrenheit, the computed values of μ_4 are necessarily far more liable to error than those for the other components, and it is rather a matter for surprise that the variations should be so small, than that they should reach the actual quantities mentioned.

The values of μ in all cases depending on that of the angle whose tangent is p/q, the consistency of the value of μ implies consistency in the ratio of p to q. At the same time as $P = \sqrt{(p^2 + q^2)}$ a considerable variation of the absolute value of P is quite compatible with consistent or invariable values of μ, and such variation in P will not tend to discredit the evidence in favour of such values of μ being trustworthy.

It may here also be noticed that as the value of P may obviously be expressed as $p/\sin x$, where $\tan x = p/q$, it follows that if the value of x, and consequently the epoch of maximum phase be regarded as fixed, for any time or place, then P will simply vary as p.

On the whole it may be regarded as sufficiently established that the computed components P and μ represent well marked truly periodical variations, even, as far as the fourth order, in which the maximum value of P hardly exceeds one-third of a degree Fahrenheit.

The component of the first order, which in the winter months is more than double the magnitude of any other, and in the summer more than ten times as large as any of them, gives the dominant character to the diurnal curve of temperature. There is an obvious tendency for high or low values of P_1 to be associated with high and low values, respectively, in the other components, though there are many deviations from such a rule.

In the series of 20 years instances may be found in almost every month, of variations in the value of P_1 for different years, of as much as 100 per cent., and the maximum values of the amplitude P in all components is frequently double the minimum. Nevertheless, these irregularities for the most part disappear even in the mean of a series of five years, and the monthly mean values for 20 years are as a whole remarkably consistent, the mean difference between the five-year and the 20-year values being less than 5 per cent.

The progression of the magnitude of P_1 in the course of the year follows approximately the Sun's meridional zenith distance, and the empirical formula $P_1 = 10 \cos z - \cdot 91$ gives a close approximation to the mean monthly values shown in the Tables, if a "lagging" of about eight or ten days is allowed in reckoning the zenith distance, as the following comparison will show:—

Month.	Meridional zenith distance.		Cos z.	Value of P_1.		Error of formula.
				From formula.	From tables.	
	°	′				
January . .	73	37	·282	1·91	1·90	+ ·01
February . .	66	47	·394	3·03	3·16	− ·13
March . . .	55	42	·564	4·73	4·67	+ ·06
April . . .	44	31	·713	6·22	6·50	− ·28
May	36	4	·808	7·17	7·30	− ·13
June	29	23	·871	7·80	7·71	+ ·09
July	29	11	·873	7·82	7·75	+ ·07
August . . .	34	29	·814	7·23	7·17	+ ·06
September . .	45	39	·699	6·08	6·46	− ·38
October . . .	57	20	·540	4·49	4·16	+ ·33
November . .	67	47	·378	2·87	2·80	+ ·07
December . .	73	38	·282	1·91	1·65	+ ·26

The amplitude of the component of the second order, P_2, has two clearly marked maxima, about the time of the equinoxes, with a principal maximum at midsummer. The component of the third order, P_3, varies in a converse manner, having two well marked minima at the time of the equinoxes, with a principal maximum at midsummer. In the fourth order, P_4 appears to combine the characters of the two former, having two maxima near the equinoxes, and a principal minimum in the winter.

The annual variation of the values of P_2 and P_3 will be represented, with a fair degree of approximation, by the expressions

$$P_2 = 1{\cdot}08 + {\cdot}20 \cos(\lambda + 126°) + {\cdot}41 \cos(2\lambda - 2°)$$
$$P_3 = {\cdot}42 + {\cdot}16 \cos(\lambda + 260°) + {\cdot}10 \cos(2\lambda - 172°),$$

in which λ is the Sun's longitude. The term involving cos 2λ gives rise, in the value of P_2, to the two maxima at the equinoxes, and in the value of P_3 to the two minima at the same seasons. The comparison of the observed and computed values of the two components for the several months is given below.

Month.	P_2. Observed.	P_2. Calculated.	P_2. Difference.	P_3. Observed.	P_3. Calculated.	P_3. Difference.
January	·94	·91	− ·03	·36	·37	+ ·01
February	1·26	1·22	− ·04	·30	·30	·00
March	1·34	1·38	+ ·04	·18	·29	+ ·11
April	1·21	1·17	− ·04	·48	·40	− ·08
May	·71	·76	+ ·05	·63	·54	− ·09
June	·56	·51	− ·05	·61	·62	+ ·01
July	·66	·70	+ ·04	·65	·58	− ·07
August	1·11	1·18	+ ·07	·55	·46	− ·09
September	1·71	1·57	− ·14	·29	·37	+ ·08
October	1·51	1·55	+ ·04	·29	·34	+ ·05
November	1·17	1·17	·00	·40	·39	− ·01
December	·76	·85	+ ·09	·33	42	+ ·09
		Sum	·63	..	..	·69
		Mean	± ·05	..	..	± ·06

It has already been remarked that the epoch of the maximum phase of the first three components appears to be earlier in the summer and later in the winter.

In the first order the mean value of μ is 214°, corresponding to 2 h. 26 m. P.M., the variation due to season being about 12°, or 48 minutes of time, by which amount the maximum is earlier in June and July than in December.

In the second order the first maximum in June is 20°, or 1 h. 20 m. earlier than in January. In the third order the difference in the same direction is 63°, or 4 h. 12 m. of time.

In the fourth order, as before noticed, there is some doubt as to the manner in which the change of positions of the summer and winter maximum is brought about. From March, when the first maximum occurs about 60° after midnight, or at 4 A.M., there is no doubt a retrogression, as in the other components, till June, when the maximum occurs 16° after midnight, or at 1 h. 4 m. A.M.; this is followed by a progression between June and October, when the maximum having become later, is again at about 60°, or 4 A.M. But a sudden change takes place in passing from October to November, which might be attributed either to the time of maximum rapidly advancing, that is, occurring later, or to its sudden recession, or becoming earlier; and, in whichever way it is brought about, one of the recurring epochs of maximum is established, from November to January, at about 10° after midnight. There is a like sudden change between January and February in the opposite direction, which again brings the maximum to about 60° from midnight, or 4 A.M. It will be seen that in February and November the absolute amplitude of this component is very small, and probably these sudden changes are coincident with the component becoming zero. (See Plate 23.)

Remembering that the fourth component of the diurnal curve includes a series of four undulations 90° apart, the explanation of what has just been stated, is probably to be found in a rapid change of conditions, under which the position of the first or earliest of these undulations recedes, until its place is taken by what was the second; so that as the maximum of the first undulation gradually becomes earlier, and at length occurs at 0°, or midnight, the maximum of the second undulation is approaching 90°, or 6 A.M., from which position it rapidly further recedes between January and February, in the last of which months it is found at 60°, or 4 A.M. The converse of such a process would explain the sudden change between October and November. On this hypothesis the numerical value of μ_4 in the months of November, December, and January, as given in the Tables, should be increased by 90° to render them properly comparable with the values in the other months. This would change the mean value for the year from 35° to 57°.

In proportion as the diurnal curve of temperature tends to greater simplicity, the magnitude of the component of the first order exceeds that of the others, and, in the months of May, June, and July, in which the amplitude of the first component is more than ten times that of any of the others, the temperature during the day, between the hours of 8 A.M. and 8 P.M., hardly deviates from a curve of sines. The mean temperature of the day coincides almost exactly with the temperature of the last-named hours, and the excess of the diurnal maximum over the mean hardly differs from the value of P_1, which, as before shown, is directly dependent on the Sun's meridional zenith distance. (Plate 21.)

The periodical variations in the amplitudes and epochs of the second, third, and fourth components, which are indications of the departures of the hourly temperatures from the simple curve of sines represented by the first component, are, without doubt, connected with the varying length of the day and other influences dependent on the time of year, among which the direction of the prevailing winds, the greater or less transparency of the atmosphere, and the amount of vapour will have places. All of these, however, will be connected in a more or less direct manner with the Sun's position and surrounding terrestrial conditions, though an expression for this connection may be difficult to discover or define.

The relation of the epoch of the first maximum in the third component to the time of sunrise—which, though directly dependent on the Sun's declination, may, of course, equally be regarded as a function of the Sun's longitude—seems to be decidedly marked; the former occurring, on the average of the whole year, at an interval of 48°, or 3 h. 12 m. earlier than the latter, or, what is the same thing, the first minimum occurring 12° or 48 minutes after sunrise, the mean deviation of the interval from that average being only 7°, or 28 minutes of time. A reference to Table B will illustrate this.

The periodical variation in the value of μ_3 leads to the third component having a *positive* maximum about 1 P.M. during the winter months, from October to February, which will be accompanied by maximum *negative* values four hours earlier and four hours later, corresponding with the *reduced* temperature in the mornings and afternoons of the *shorter* days. (Plate 23.)

In the summer months, from April to August, μ_3 has a maximum *negative* value about 1 P.M., instead of a *positive* maximum as in winter; and this, being accompanied by two *positive* maxima, one four hours earlier and the other four hours later, will in like manner correspond to the *higher* temperature in the mornings and afternoons of the *longer* day.

It will be seen that the positions of the midsummer and midwinter maximum phases correspond respectively to days of 16 hours with nights of 8 hours, or days of 8 hours with nights of 16 hours, and that at these seasons, when the variations of temperature due to these differences are greatest, the values of the amplitude of the component are also at a maximum. At the equinoxes, with a 12 hours day and night, the amplitude of the component has a minimum value, and the transition of the position of the maximum phase takes place as already described.

It might, perhaps, be expected that the change in the position of the maximum phase of the fourth component, μ_4, would take place in an analogous manner, in connection with days and nights of 6 and 18 hours duration respectively, corresponding to the epoch of the component. But such days and nights will only occur in higher latitudes than those of our observatories, and no data are available by which to test such a suggestion.

Although the several harmonic components of the temperature curve cannot be regarded as indication of specific physical efficient causes, acting at definite periodical harmonic intervals, the graphical representations of the series of monthly temperature curves and their components, which are given in the plates accompanying this paper, present some points to which attention may usefully be drawn.

As before noticed, the deviation of the *day* temperature from the first component is extremely small in the months of May, June, and July, during which between 8 A.M. and 8 P.M. the other components nearly cancel one another. From September to March however, the temperature during the day hours rises considerably above the first component, the second and third component either being both positive and operating in the same direction, or the third component if negative being overpowered by the other two, which from 10 A.M. to 4 P.M. are always positive.

The temperature curve between the hours of 4 A.M. or 5 A.M. and 7 A.M. or 8 A.M. always falls below the first component.

The first component having its maximum about 2 P.M. is always negative between 8 P.M. and 8 A.M.

The second component having a day maximum which varies between 11.30 A.M. to 1.30 P.M. is always negative between 4 A.M. and 8 A.M. In the summer months when the third component is largest, it is also negative between 4 A.M. and 7 A.M., and at other seasons, when it would operate in an opposite direction, its relatively small magnitude renders its effects unimportant.

The second component always having a maximum near noon will also have another near midnight.

In the summer months when the third component has a minimum shortly following noon, it will have a maximum shortly following midnight, that is nearly at the same time as the second component, and at this season the night temperature is found to be considerably above the first component. In the winter months the third component becomes negative during the hours when it was before positive, and the departure of the night temperature from the first component is much smaller.

In the summer months the time of morning mean temperature is nearly when the first component becomes zero, the second and third components then balancing one another.

In the winter the hour of morning mean temperature is later, and occurs when a positive value of the first component equals a negative value of the second.

The time of afternoon mean temperature throughout the year is somewhat either before or after 7 P.M., and almost exactly coincides with the time when the first and second components are equal but with opposite signs, the former being positive and the latter negative.

In the summer months the whole of the components are negative between the hours of 3 A.M. and 6 A.M., corresponding with the absolute minimum about this time.

In the winter the third and fourth components are not negative till after 6 A.M., while the negative branch of the first component is extended almost to 9 A.M., and the absolute minimum is found correspondingly later between 7 A.M. and 8 A.M.

The hour of absolute maximum is nearly coincident with that of the dominant first component, which is always between 2 P.M. and 3 P.M., the modifications due to the second component, which also has a maximum between noon and 2 P.M., being of secondary importance.

Sunrise in December is about an hour and-a-half before the time of mean temperature, while in June it is more than four hours before that time.

On the other hand, while sunset in December is rather more than three hours before the time of mean temperature, in June it is about half-an-hour after that time.

Also it will be found that in January whereas the temperature is above the mean of the whole 24 hours for not more than $8\frac{3}{4}$ hours, in June it is above the mean for nearly 12 hours.

It may here be pointed out that the *rationale* of some of the empirical rules for obtaining the mean daily temperature, from a limited number of observations made at certain stated hours, is supplied by reference to the harmonic expressions for the hourly deviations of the temperature from the mean of the whole day.

In the first place it is obvious, that by adding together the harmonic expressions for any two hours, twelve hours apart, the whole of the *odd* components disappear, and that the sum is twice the mean value added to twice the sum of the *even* components of the selected pair of hours, which are respectively equal to one another. Disregarding the components above the fourth order, as may be done in practice, if the hours selected be such that the component of the second order is zero, which will be the case when the hours correspond to $45° + \mu_2$, or $135° + \mu_2$, then half the sum of the observed temperatures at the selected pair of hours will be equal to the true daily mean added to the value of the component of the fourth order for the selected hours, which at English stations will hardly amount to so much as half a degree Fahrenheit. At Greenwich it will be found that in January the mean of observations at 4.30 A.M., and 4.30 P.M., or at 10.30 A.M., and 10.30 P.M., differ by less than $0°\cdot1$ from the true mean, and a similar result will be obtained in June by taking the mean of observations at 3 A.M. or 9 A.M., and at the corresponding afternoon hours.

For like reasons it will be seen that by taking the mean of observations at *any four* hours, at equal intervals of six hours, not only will the whole of the *odd* components disappear, but those of the *second* order also, so that the result will only differ from the true mean by the amount of the component of the fourth order for the selected hours. As the fourth component disappears at hours when $\mu_4 \pm 22\frac{1}{2}°$ equals $0°$ or $180°$, the hours at Greenwich which will give the best result will be found to be 2, 8, 14, and 20, or 5, 11, 17, and 23.

Again, if the mean of any *three* hours, at equal intervals of eight hours, be taken, it will be seen that the sums of the *first*, *second*, and *fourth* components disappear, and that the result will only differ from the true daily mean by the amount of the third component for the selected hours, which at English stations will hardly exceed three-quarters of a degree. The best result will be obtained when the selected hours correspond to $\mu_3 \pm 30° = 0°$, or $180°$, when the third component becomes zero, and at Greenwich for the greater part of the year this condition will be nearly complied with by the hours 3, 11, and 19, or 7, 15, and 23.

It will be readily understood that the true reason for such close approximations being so easily obtained, is the great preponderance of the first and second components of the temperature variation over all the rest.

Temperature at the Seven Observatories.

The mechanical analyser, by means of which the harmonic components of the temperature curves for these observatories have been obtained, is only adapted for computing the coefficients of the first three orders, so that the constants for the fourth order are not given in the published tables.

The values of P and μ were calculated from the values of the p, q coefficients, which are obtained by means of the instrument, in the same way as those for Greenwich.

An inspection of the table C and D, which are annexed, and contain a summary of the results, will at once show that in their main characteristics the results closely resemble those for Greenwich, and for this reason it will not be necessary to discuss them at great length.

The amplitude of the component of the first order P_1 is, however, in all cases below that of Greenwich, the lowest values being those of Valencia and Falmouth, no doubt due to their position on the coast, with means for the year of $2^{\circ}\cdot28$ and $2^{\circ}\cdot35$, compared with $5^{\circ}\cdot10$ at Greenwich.

The Kew values most resemble those of Greenwich, but the mean maximum is more than one degree less, and the mean for the year about half a degree less. These differences are probably in a considerable degree due to differences of exposure, and local conditions of soil, &c.

The mean values of μ_1 for the year referred to local apparent time, lie between 205° and 220°, that for Greenwich being 214°. The summer values are somewhat below the mean, and the winter values somewhat above it, as is the case at Greenwich.

The amplitude of the first component conforms approximately, but not so closely as in the case of Greenwich, to the sine of the sun's meridian altitude, with a flattening of the curve in the summer months, and a tendency at some stations to a maximum value in May.

The component of the second order in all cases shows the double maximum at the equinoxes and the minimum value in summer. The numerical values of P_2 are, as a rule, below those at Greenwich, the yearly means varying between $0^{\circ}\cdot84$ and $0^{\circ}\cdot61$, against $1^{\circ}\cdot08$ at Greenwich; Kew, as before, most closely resembling Greenwich.

The values of μ_2 generally follow the same law as at Greenwich, the epoch of maximum being earlier in the summer and later in the winter, this character being specially marked at Aberdeen, where the summer value of μ_2 is $-44°$, and the winter value 20°, a difference of 64°, or more than four hours of time, a result no doubt connected with the higher latitude of that station, the earlier sunrise and the longer day.

The component of the third order also in all cases closely resembles that at Greenwich, P_3 having the double minimum at the two equinoxes, and a maximum in summer. The mean yearly value is again somewhat below that for Greenwich, varying from $0^{\circ}\cdot23$ to $0^{\circ}\cdot38$, the Greenwich value being $0^{\circ}\cdot42$.

The values of μ_3 accord very closely with those at Greenwich where the mean yearly value is 41°, the mean yearly values at the seven observatories ranging between 37° and 43°. The variations of the epochs of maximum from winter to summer are at all stations well marked, and at Aberdeen, as was the case with the component of the second order, μ_3 shows an exceptionally low value in the summer, differing about 70°, or nearly five hours of time, from the winter epoch.

The expressions for the annual variations of the values of P_2 and P_3, derived from the means of the observations at the seven observatories, differ little from those before given for the Greenwich values, allowance being made for the smaller amplitude of all the components. They are as follows :—

$$P_2 = {\cdot}68 + {\cdot}14 \cos (\lambda + 105°) + {\cdot}21 \cos (2\lambda - 8°),$$
$$P_3 = {\cdot}30 + {\cdot}13 \cos (\lambda + 260°) + {\cdot}07 \cos (2\lambda - 166°).$$

The comparison of the observed and computed monthly values of the components for several months is given below.

Months.	P_2.			P_3.		
	Observed.	Calculated.	Difference.	Observed.	Calculated.	Difference.
January .	·62	·62	·00	·22	·22	·00
February .	·78	·78	·00	·17	·18	+·01
March . .	·93	·85	−·08	·12	·19	+·07
April . .	·75	·63	−·12	·32	·30	−·02
May . . .	·42	·49	+·07	·53	·41	−·12
June . . .	·33	·33	·00	·43	·46	+·03
July . . .	·35	·40	+·05	·42	·41	−·01
August . .	·66	·65	−·01	·40	·33	−·07
September .	·97	·90	−·07	·27	·25	−·02
October . .	1·02	·94	−·08	·15	·23	+·08
November .	·79	·78	−·01	·24	·28	+·04
December .	·59	·63	+·04	·22	·26	+·04
		Sum . .	·53		Sum . .	·51
		Mean . .	·04		Mean . .	·04

On the whole it may be regarded as well established by the substantial consistency of these results, that they truly indicate the chief characters of the diurnal inequality of temperature in the British Isles; and they leave no room to doubt that the variations which recur with such remarkable regularity from year to year, and are observed at so many different places, extending to quantities so small as those represented by the third and fourth order of harmonic components, are due to the operations of determinate physical causes, the effects of which this system of analysis enables us to distinguish and record with remarkable and unexpected precision.

I am not in a position to indicate, further than has already been done, any direct or precise relation between the observed thermometric results thus recorded, and the varying place of the Sun, on which in combination with the latitude and local influences of different descriptions they doubtless depend. The intermittent character of solar heat introduces a discontinuity of action which renders its connection with the resulting phenomena specially difficult of representation by algebraical expressions.

Acting on a suggestion of Professor G. DARWIN, I have calculated the harmonic constants that would reproduce a curve indicating an intermittent action such as that of the Sun, continuing only during a portion of the day, and commencing and ending abruptly at sunrise and sunset. The results are of some interest, and serve to throw light on the character and signification of the harmonic components of temperature that have been under discussion.

Such a calculation obviously disregards all cooling effects, and only deals with the Sun's heating action, which I have assumed to be proportional to the sine of his altitude; and with a view to obtaining figures in some degree comparable with those obtained from actual observation, and following the analogy of the value of P_1, as previously pointed out, the total heating effect has been taken to be ten times the sine of the Sun's altitude, the power of a vertical Sun being that represented by ten.

On this assumption I have calculated the Sun's altitude for each hour of the day for midwinter, the equinox, and midsummer for certain selected latitudes, and corresponding heating effects. These computations supply a series of hourly values having their maximum at noon and becoming zero at sunrise and sunset, and disappearing so long as the Sun is below the horizon. Treating these in the usual manner, the resulting harmonic components as far as the fourth order are shown in the following Table F:—

TABLE F.

Latitude.	Midwinter.				Equinox.				Midsummer.			
	Components.				Components.				Components.			
	P_1.	P_2.	P_3.	P_4.	P_1.	P_2.	P_3.	P_4.	P_1.	P_2.	P_3.	P_4.
0°	−4·58	+1·92	0	− ·40	−5·06	+2·14	0	−·45	−4·58	+1·92	0·	−·40
20	−3·40	+1·70	− ·26	− ·30	−4·74	+2·02	0	−·43	−5·25	+1·74	+ ·29	−·30
30	−2·76	+1·42	− ·28	− ·11	−4·35	+1·68	0	−·37	−5·27	+1·55	+ ·38	−·21
40	−1·92	+1·23	− ·43	− ·06	−3·86	+1·60	0	−·35	−5·12	+1·22	+ ·43	−·05
45	−1·51	+1·03	− ·42	+ ·03	−3 52	+1·49	0	−·35	−5·19	+1·05	+ ·37	+·06
51½	−1·01	+ ·77	− ·39	+ ·12	−3·15	+1·33	0	−·30	−4·76	+ ·79	+ ·40	+·18
65	0	0	0	0	−2·21	+ ·95	0	−·20	−3·85	0	+ ·05	+·09

As from the nature of the hypothesis adopted the diurnal curve analysed is in all cases symmetrical on either side of noon, the values of q are all zero. Also the values of P and p become identical; the negative sign in the above table signifies that the component has a negative maximum value at midnight; and the positive sign that the component has a positive maximum value at the same hour. The values of μ for the several components will be seen to be as follows:—For the first component $\mu_1 = 180°$, or noon; for the second $\mu_2 = 0°$, or midnight; for the third $\mu_3 = 0°$ for the summer, and $\mu_3 = 60°$ for the winter, the change taking place at the equinox when the component becomes zero; for the fourth, in the lower latitudes, $\mu_3 = 45°$ at all seasons, in the higher latitudes at the equinox $\mu_4 = 45°$, passing to 0° both in the winter and summer.

For comparison with the above results, are given below the components of the diurnal temperature curve as actually observed at certain selected stations, varying in latitude, for the three seasons of the year.

TABLE G.

Stations.	Mid-winter.				Equinox.				Mid-summer.			
	Components.				Components.				Components.			
	P_1	P_2.	P_3.	P_4.	P_1.	P_2.	P_3.	P_4.	P_1.	P_2.	P_3.	P_4.
Singapore. Lat. 1° 15′ N.	−5·02	+1·78	−·28	−·18	−6·47	+2·04	+·68	−·48	−4·62	+1·54	+·32	−·51
Hong Kong. Lat. 22°18′ N.	−2·39	+1·01	−·67	−·81	−1·98	+ ·70	−·02	−·12	−1·86	+ ·63	+·09	−·13
Lyons. Lat. 45°46′ N.	−2·51	+1·01	−·41	+·07	−6·26	+1·49	+·11	−·31	−7·55	+ ·76	+·59	+·16
Greenwich. Lat. 51°30′ N.	−1·65	+ ·76	−·33	+·09	−4·67	+1·34	+·18	−·23	−7·71	+ ·56	+·61	+·21
Fort Rae. Lat. 62°40′ N.	−1·09	+ ·67	−·31	+·29	−7·71	+1·90	+·42	−·50	−6·01	+ ·59	+·19	+·06

The signs indicate the sign of the components at midnight.

It will hence be seen that while the intermittent curves representing the heating power of the Sun, under varying conditions of meridional altitude and length of day, are fairly well reproduced by combining the components of the first four orders having the values shown in Table F, these components bear a very close resemblance to those shown in Table G, obtained from the observed temperatures of places at the latitudes and seasons corresponding to those adopted in the computations from the intermittent curves.

The conclusion is unavoidable, that although both in the real and hypothetical cases the harmonic components, when combined, are truly representative of the peculiar forms of the curves from which they were derived, this affords no true indication of the existence of distinct physical influences operating in recurring cycles of 24, 12, 8, and 6, corresponding to the four orders of components; but that the results are, to a great extent, due to the particular form given to the analysis.

The component of the first order represents a variation from the mean value, which is symmetrical on either side of the epoch of its maximum, and necessarily involves a negative departure from the mean, equal to a corresponding positive departure at the hour of maximum, and twelve hours distant from the maximum.

As the diurnal curve of temperature is not symmetrical in relation to the mean value, the maximum day temperature being much more in excess of the mean than the minimum night temperature is below it, the first component, which is symmetrical in this respect, must be modified by the other components; and that of the second order, which has one of its maxima not far removed from the epoch of minimum of the first component, supplies the chief portion of the compensation necessary to correct the excess of that minimum over the true minimum.

Further, from the character of the analysis, the third component will be zero when the diurnal curve is symmetrical, but with contrary signs on either side of the hours half-way between noon and midnight, that is when the length of the day and night are each 12 hours. Any departure from this equality will introduce a component of the third order; with the result, that with a day shorter than 12 hours, one maximum phase will be between 6 A.M. and 6 P.M., and the other two in the hours before 6 A.M. and after 6 P.M.; while with a day longer than 12 hours, two maxima will be between 6 A.M. and 6 P.M., and the other in the hours after 6 P.M. and before 6 A.M. In the former case the two negative phases of the component will correspond with the reduced temperature in the morning and afternoon of the shorter day, and in the latter the two positive phases will correspond with the increased heat of the mornings and afternoons of the longer days.

It will also be apparent that with a day of 8 hours, and a night of 16 hours, or *vice versâ*, the epochs of the third component would tend to synchronize with the duration of the night and day, and its amplitude might be expected to be then greater, which is seen to be the case.

Analogous considerations will apply to the component of the fourth order. A positive maximum phase at or near midnight would give two maxima, near 6 A.M. and 6 P.M., respectively, corresponding to the long days in high latitudes in the summer, and also two negative minima at or near 9 A.M. and 3 A.M. respectively, corresponding to the short days in winter, in high latitudes. The Tables F and G both show P_4 with a positive sign under the circumstances just stated.

Again a negative phase at or near midnight would correspond to two negative phases at or near 6 A.M. and 6 P.M., respectively, which would correspond to the days and nights of nearly 12 hours in the lower latitudes and at the equinoxes, which conditions are also shown to exist by the two Tables before referred to, the sign of P_4 being in all cases negative at the equinox.

In connection with this view of the temperature components it may be noticed that if instead of reckoning the epochs of maxima as the phase nearest to midnight, that nearest noon were adopted, it would be found that the usual time of maximum phase of all the components is not far removed from noon, affording strong evidence that all these phases are closely dependent on the passage of the Sun over the meridian.

For Greenwich the following would be the results :—

	December.	March.	June.
	°	°	°
1st component	222	215	210
2nd ,, ...	200	198	181
3rd ,, ...	194	. .	(193)
4th ,, ...	190	(193)	196

In case of the third and fourth components the figures enclosed in brackets ( ) are epochs of minimum.

In conclusion, I would observe that in the course of the preparation of the data on which this discussion has been based, I have computed the harmonic components of the temperature curves of many other places besides those here specially noticed, and that the results obtained from them entirely confirm those now set forth. I am not, however, in a position at the present time to present any satisfactory details of these investigations, involving as they do very tedious computations, which I have not yet been able to carry out in a systematic or complete shape.

The importance of the subject in connection with the study of the diurnal variations of atmospheric pressure cannot be overstated, and in the second part of this memoir, which will be devoted to that question, I shall have occasion to revert to it. Meanwhile I would invite the co-operation of persons interested in this branch of physics in the collection of data relating to temperature as complete as those now available in the case of atmospheric pressure.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

NOTE.—In 1879 Sir G. STOKES communicated to the Meteorological Council, of which he was then a member, copies of letters addressed by him to Sir G. AIRY, containing the results of computations of the harmonic components of the Greenwich diurnal temperature curve, made in the ordinary manner, which differs somewhat from that adopted by me. These results supply the coefficients up to the fourth order for each of the 20 years of the Greenwich series, separately, and those of the fifth and sixth orders for the mean of the 20 years taken together. They are almost identical with the values given in the volume of tables published by the Meteorological Council, and the comparison of the means of the two sets of computations may be of some interest.

	p_1.	q_1.	p_2.	q_2.	p_3.	q_3.	p_4.	q_4.	p_5.	q_5.	p_6.	q_6.
Sir G. STOKES	−4·280	−2·722	+·883	+·563	+·063	+·119	−·043	−·014	−·001	−·026	−·003	−·008
Meteorological Tables . .	−4·282	−2·738	+·885	+·557	+·066	+·118	−·046	−·015				

	P_1.	P_2.	P_3.	P_4.	P_5.	P_6.
Sir G. STOKES	5·072	1·047	·135	·045	·026	·009
Meteorological Tables . .	5·083	1·046	·134	·047		

It has not been thought worth while to repeat the detailed figures for the separate years, as they are virtually identical with those given in the Meteorological Office Tables.

Referring to a comparison that he had made between the mean observed hourly temperatures and the values obtained by computation from the daily means and the harmonic coefficients, Sir G. STOKES remarked that "the minute fourth order is swallowed up, even in a mean of 20 years' series, by the uncertainty in the amount of the diurnal fluctuation, not to speak of the much larger uncertainty in the mean temperature for a day. Nevertheless, it appears from the figures, that though this order is so minute, and though its effect on the mean temperature at any particular hour is trifling compared with the average variation from year to year of the same hour, it still emerges roughly with tolerable certainty from the mean of a good many years."

This conclusion is fully confirmed by the more complete examination of the results obtained from the mean *monthly* values, much of the strong evidence of the periodicity represented by the minute fourth order of components being lost by dealing with the mean *yearly* values.

TABLE A.—Mean Values (reckoned from Mean Midnight) of the p, q Coefficients for the First Four Orders of Harmonic Components of the Diurnal Inequality of Temperature at Greenwich, for each Month of the Year, obtained from 20 Years' Observations from 1849 to 1868.

Months.	p_1.	q_1.	p_2.	q_2.	p_3.	q_3.	p_4.	q_4.	Mean temp. T.
January	−1°·45	−1°·20	+ °·64	+ °·69	− °·24	− °·26	+ °·04	+ °·04	38°·9
February	−2·39	−2·06	+ ·88	+ ·89	− ·23	− ·17	·00	− ·07	39·7
March	−3·71	−2·82	+1·02	+ ·87	− ·06	+ ·13	− ·12	− ·19	41·5
April	−5·46	−3·51	+1·04	+ ·56	+ ·27	+ ·36	− ·15	− ·08	47·2
May	−6·34	−3·61	+ ·63	+ ·17	+ ·50	+ ·38	− ·01	+ ·09	52·7
June	−6·69	−3·83	+ ·50	+ ·04	+ ·46	+ ·39	+ ·10	+ ·17	59·8
July	−6·58	−4·08	+ ·57	+ ·23	+ ·50	+ ·38	− ·01	+ ·12	62·5
August	−6·06	−3·83	+ ·95	+ ·53	+ ·38	+ ·39	− ·16	+ ·01	61·9
September	−5·60	−3·21	+1·49	+ ·83	+ ·06	+ ·25	− ·23	− ·23	57·5
October	−3·61	−2·04	+1·35	+ ·74	− ·25	− ·04	− ·10	− ·10	50·9
November	−2·29	−1·60	+ ·96	+ ·67	− ·35	− ·18	+ ·03	+ ·01	42·8
December	−1·22	−1·07	+ ·59	+ ·47	− ·25	− ·21	+ ·06	+ ·05	40·8
Mean 20 years	−4·282	−2·738	+ ·885	+ ·557	+ ·066	+ ·118	− ·046	− ·015	49·69

TABLE B.—Values of the Amplitude P, and the Apparent Time of the First Maximum μ, for the First Four Orders of Harmonic Components of the Diurnal Inequality of Temperature at Greenwich for each Month of the Year, for Five-Yearly Periods between 1849 and 1868.

	Five-yearly periods.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
P_1	1st . .	1·90	3·25	4·94	5·80	6·97	7·76	7·39	6·85	6·20	3·94	2·74	1·44	4·93
	2nd . .	2·00	3·50	5·05	7·19	7·25	8·13	7·43	7·76	6·98	4·28	2·61	1·74	5·33
	3rd . .	1·99	3·17	4·42	6·05	7·24	6·55	7·62	6·75	5·82	3·93	2·89	1·79	4·86
	4th . .	1·71	2·71	4·27	6·94	7 74	8·40	8·57	7·30	6·74	4·47	2·97	1·62	5·29
	Mean . .	1·90	3·16	4·67	6·50	7·30	7·71	7·75	7·17	6·46	4·16	2·80	1·65	5·10
P_2	1st . .	·97	1·20	1·40	1·04	·66	·64	·72	1·05	1·57	1·50	1·09	·78	1·05
	2nd . .	1·00	1·33	1·43	1·45	·75	·63	·63	1·32	2·01	1·59	1·15	·81	1·18
	3rd . .	1·00	1·32	1·26	1·07	·82	·49	·57	·98	1·36	1·43	1·22	·77	1·03
	4th . .	·80	1·18	1·27	1 27	·59	·47	·72	1·07	1·83	1·66	1·22	·69	1·06
	Mean . .	·94	1·26	1·34	1·21	·71	·56	·66	1·11	1·71	1·54	1·17	·76	1·08
P_3	1st . .	·40	·28	·16	·49	·65	·73	·64	·56	·27	·23	·40	·28	·43
	2nd . .	·34	·31	·22	·49	·63	·58	·62	·52	·37	·35	·38	·35	·43
	3rd . .	·34	·28	·14	·47	·48	·43	·61	·46	·30	·23	·40	·36	·38
	4th . .	·35	·32	·19	·45	·77	·69	·72	·67	·23	·35	·43	·33	·46
	Mean . .	·36	·30	·18	·48	·63	·61	·65	·55	·29	·29	·40	·33	·42
P_4	1st . .	·09	·12	·27	·18	·08	·15	·18	·20	·34	·14	·07	·10	·16
	2nd . .	·08	·11	·27	·24	·14	·24	·15	·15	·36	·15	·06	·08	·17
	3rd . .	·11	·08	·18	·19	·12	·17	·19	·15	·32	·16	·05	·10	·16
	4th . .	·09	·11	·19	·19	·13	·29	·17	·19	·33	·23	·11	·09	·18
	Mean . .	·09	·11	·23	·20	·12	·21	·17	·17	·34	·17	·07	·09	·16

TABLE B (continued).—Values of the Amplitude P, and the Apparent Time of the First Maximum μ, for the First Four Orders of Harmonic Components of the Diurnal Inequality of Temperature at Greenwich for each Month of the Year, for Five-Yearly Periods between 1849 and 1868.

	Five-yearly periods.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
μ_1	1st . .	222°	217°	214°	212°	211°	208°	208°	213°	211°	212°	218°	223°	214°
	2nd . .	216	216	217	212	210	211	211	213	212	212	220	226	215
	3rd . .	213	216	214	214	212	209	211	212	210	213	218	217	213
	4th . .	217	220	215	113	210	211	212	213	211	216	218	222	215
	Mean . .	217	217	215	213	211	210	210	213	211	213	219	222	214
μ_2	1st . .	22	21	18	9	9	− 8	0	16	19	19	22	18	14
	2nd . .	19	17	17	14	6	6	8	15	15	18	20	20	14
	3rd . .	23	19	22	12	17	9	11	17	13	18	20	23	17
	4th . .	20	20	16	17	− 2	− 1	13	14	16	17	21	20	14
	Mean . .	21	19	18	13	8	1	8	16	16	18	21	20	15
μ_3	1st . .	75	69	40	14	14	16	12	15	21	66	75	76	41
	2nd . .	74	70	30	19	14	12	12	18	36	68	73	73	41
	3rd . .	73	69	40	15	11	13	10	13	23	68	72	72	40
	4th . .	72	66	49	22	13	12	11	16	26	62	70	77	41
	Mean . .	74	69	40	18	13	13	11	16	27	66	73	74	41
μ_4	1st . .	12	56	58	47	25	16	23	46	58	62	25	12	58
	2nd . .	14	57	57	55	27	20	30	47	60	62	16	14	60
	3rd . .	10	65	56	48	16	17	24	38	57	51	− 8	0	53
	4th . .	5	68	61	61	24	11	7	46	57	62	9	15	57
	Mean . .	10	62	58	53	23	16	21	44	58	59	11	10	57
	Time of sunrise	118°	106°	91°	77°	66°	58°	61°	72°	87°	101°	115°	122°	—

TABLE C.—Mean Values (reckoned from Greenwich Mean Midnight) of the p, q Coefficients for the First Three Orders of Harmonic Components, of the Diurnal Inequality of Temperature at the Seven Observatories of the Meteorological Office, for each Month of the Year, obtained from Twelve Years' Observations from 1871 to 1882.

	Valencia.	Armagh.	Falmouth.	Glasgow.	Stonyhurst.	Aberdeen.	Kew.
Longitude correction local midnight later than Greenwich midnight	10° 18′	6° 39′	5° 4′	4° 18′	2° 28′	2° 6′	0° 19′
Months.	p_1.						
January	— ·74	— ·74	— ·74	— ·69	— ·91	— ·79	—1·27
February	—1·02	—1·36	—1·08	—1·18	—1·32	—1·40	—1·64
March	—1·72	—2·35	—1·77	—2·17	—2·53	—2·06	—3·16
April	—2·28	—3·38	—2·27	—3·37	—3·87	—2·56	—4·33
May	—3·02	—4·10	—3·08	—4·10	—4·69	—3·29	—5·09
June	—2·63	—3·83	—3·20	—4·30	—4·38	—3·31	—4·98
July	—2·46	—3·38	—3·39	—3·73	—3·95	—3·26	—4·77
August	—2·53	—3·26	—2·87	—3·57	—3·61	—3·05	—4·66
September . . .	—2·19	—2·82	—2·31	—2·91	—3·31	—2·99	—4·31
October	—1·60	—2·12	—1·62	—1·99	—2·26	—2·07	—3·23
November . . .	—1·05	—1·27	—1·09	—1·15	—1·32	—1·12	—1·87
December	— ·79	— ·84	— ·92	— ·54	— ·73	— ·67	—1·27
Mean 12 years .	—1·84	—2·45	—2·03	—2·47	— [illegible]	—2·21	—3·38

	Valencia.	Armagh.	Falmouth.	Glasgow.	Stonyhurst.	Aberdeen.	Kew.
Longitude correction local midnight later than Greenwich midnight	10° 18′	6° 39′	5° 4′	4° 18′	2° 28′	2° 6′	0° 19′
Months.	p_2.						
January	+ ·27	+·31	+·37	+·25	+·42	+·37	+ ·47
February	+ ·37	+·47	+·51	+·41	+·48	+·55	+ ·50
March	+ ·42	+·68	+·58	+·58	+·70	+·65	+ ·81
April	+ ·44	+·74	+·56	+·57	+·66	+·53	+ ·73
May	+ ·34	+·45	+·44	+·15	+·40	+·10	+ ·26
June	+ ·16	+·41	+·37	+·16	+·15	+·06	+ ·15
July	+ ·22	+·34	+·39	+·19	+·26	+·10	+ ·11
August	+ ·36	+·57	+·61	+·49	+·53	+·42	+ ·55
September . . .	+ ·55	+·80	+·71	+·77	+·90	+·76	+ ·95
October	+ ·60	+·80	+·70	+·70	+·89	+·79	+1·13
November . . .	+ ·48	+·62	+·56	+·47	+·67	+·54	+ ·79
December	+ ·38	+·37	+·49	+·27	+·36	+·35	+ ·49
Mean 12 years .	+ ·38	+·55	+·52	+·42	+·54	+·43	+ ·58

	Valencia.	Armagh.	Falmouth.	Glasgow.	Stonyhurst.	Aberdeen.	Kew.
Longitude correction local midnight later than Greenwich midnight	10° 18′	6° 39′	5° 4′	4° 18′	2° 28′	2° 6′	0° 19′
Months.	p_3.						
January	— ·03	—·10	—·11	—·03	—·12	—·09	—·15
February	— ·02	—·10	—·09	—·06	—·09	—·10	—·04
March	— ·03	—·08	—·05	—·02	—·03	—·04	—·01
April	+ ·11	+·04	+·11	+·15	+·20	+·13	+·24
May	+ ·21	+·21	+·30	+·41	+·35	+·33	+·45
June	+ ·14	+·20	+·28	+·29	+·30	+·31	+·32
July	+ ·14	+·12	+·28	+·29	+·25	+·28	+·33
August	+ ·13	+·07	+·20	+·22	+·24	+·25	+·30
September . . .	+ ·06	—·03	+·05	+·06	+·13	+·09	+·18
October	— ·06	—·18	—·10	—·11	—·11	—·13	—·13
November . . .	— ·12	—·18	—·18	—·15	—·21	—·14	—·26
December	— ·05	—·15	—·15	—·03	—·13	—·13	—·15
Mean 12 years .	+ ·04	—·02	+·05	+·09	+·07	+·06	+·09

TABLE C (continued).—Mean Values (reckoned from Greenwich Mean Midnight) of the p, q Coefficients for the First Three Orders of Harmonic Components, of the Diurnal Inequality of Temperature at the Seven Observatories of the Meteorological Office, for each Month of the Year, obtained from Twelve Years' Observations from 1871 to 1882.

	Valencia.	Armagh.	Falmouth.	Glasgow.	Stonyhurst.	Aberdeen.	Kew.
Longitude correction local midnight later than Greenwich midnight	10° 18′	6° 39′	5° 4′	4° 18′	2° 28′	2° 6′	0° 19′
Months.	q_1.						
January	−·48	−·90	−·59	−·81	−·92	−·66	−1·17
February	−·86	−1·31	−·84	−1·30	−1·21	−1·21	−1·63
March	−1·47	−2·18	−1·24	−2·07	−2·16	−1·43	−3·23
April	−1·97	−2·88	−1·46	−3·06	−2·77	−1·50	−3·53
May	−2·30	−3·34	−1·73	−3·43	−3·06	−1·70	−4·13
June	−1·81	−2·97	−1·58	−3·28	−2·85	−1·56	−4·07
July	−1·74	−2·83	−1·67	−2·84	−2·62	−1·78	−4·44
August	−1·74	−2·72	−1·49	−2·82	−2·68	−1·85	−4·08
September . . .	−1·45	−2·38	−1·27	−2·30	−2·24	−1·90	−3·42
October	−·98	−1·50	−·92	−1·73	−1·45	−1·37	−2·46
November . . .	−·62	−1·17	−·65	−·99	−·93	−·76	−1·48
December	−·53	−·86	−·52	−·79	−·77	−·36	−1·00
Mean 12 years .	−1·33	−2·09	−1·16	−2·12	−1·97	−1·34	−2·89

	Valencia.	Armagh.	Falmouth.	Glasgow.	Stonyhurst.	Aberdeen.	Kew.
Longitude correction local midnight later than Greenwich midnight	10° 18′	6° 39′	5° 4′	4° 18′	2° 28′	2° 6′	0° 19′
Months.	q_2.						
January	+·46	+·53	+·29	+·44	+·58	+·46	+·68
February	+·55	+·71	+·38	+·63	+·60	+·61	+·80
March	+·58	+·75	+·38	+·68	+·69	+·49	+1·03
April	+·58	+·45	+·27	+·60	+·53	+·07	+·56
May	+·29	+·14	−·03	+·31	+·04	−·37	+·10
June	+·19	+·05	+·04	+·10	−·14	−·40	+·01
July	+·27	+·17	+·07	+·23	+·08	−·31	+·07
August	+·47	+·48	+·24	+·55	+·34	−·15	+·43
September . . .	+·56	+·60	+·33	+·61	+·57	+·30	+·85
October	+·52	+·71	+·34	+·72	+·64	+·54	+·80
November . . .	+·50	+·59	+·27	+·53	+·53	+·43	+·67
December	+·49	+·47	+·34	+·42	+·42	+·30	+·56
Mean 12 years .	+·46	+·47	+·24	+·49	+·41	+·16	+·55

	Valencia.	Armagh.	Falmouth.	Glasgow.	Stonyhurst.	Aberdeen.	Kew.
Longitude correction local midnight later than Greenwich midnight	10° 18′	6° 39′	5° 4′	4° 18′	2° 28′	2° 6′	0° 19′
Months.	q_3.						
January	−·17	−·24	−·12	−·18	−·19	−·20	−·23
February	−·10	−·20	−·05	−·15	−·15	−·16	−·17
March	+·07	+·06	+·08	+·05	+·10	+·09	+·09
April	+·22	+·34	+·25	+·31	+·40	+·28	+·38
May	+·40	+·43	+·37	+·45	+·49	+·18	+·51
June	+·28	+·32	+·29	+·41	+·42	+·10	+·39
July	+·28	+·32	+·32	+·38	+·37	+·20	+·50
August	+·28	+·32	+·30	+·37	+·33	+·31	+·47
September . . .	+·15	+·22	+·19	+·21	+·28	+·30	+·34
October	−·04	−·08	+·01	−·10	−·03	−·01	+·03
November . . .	−·12	−·18	−·08	−·17	−·14	−·14	−·19
December	−·23	−·22	−·13	−·13	−·15	−·15	−·20
Mean 12 years .	+·09	+·09	+·12	+·12	+·14	+·07	+·16

TABLE D.—Mean Values of the Amplitude P, and of the First Maximum μ, reckoned from Local Apparent Midnight, for the First Three Orders of Harmonic Components of the Diurnal Inequality of Temperature at the Seven Observatories of the Meteorological Office, for each Month of the Year and for the entire Year, obtained from Twelve Years' Observations from 1871 to 1882.

Months.	P_1.							P_2.							P_3.						
	Valencia.	Armagh.	Falmouth.	Glasgow.	Stonyhurst.	Aberdeen.	Kew.	Valencia.	Armagh.	Falmouth.	Glasgow.	Stonyhurst.	Aberdeen.	Kew.	Valencia.	Armagh.	Falmouth.	Glasgow.	Stonyhurst.	Aberdeen.	Kew.
January	0·91	1·20	0·96	1·09	1·31	1·05	1·74	·56	·62	·48	·52	·72	·60	·84	·18	·27	·17	·19	·23	·23	·28
February	1·34	1·94	1·37	1·76	1·81	1·87	2·32	·67	·86	·64	·75	·78	·82	·95	·11	·23	·11	·18	·17	·19	·19
March	2·27	3·22	2·17	3·02	3·34	2·51	4·53	·73	1·02	·71	·92	1·00	·82	1·32	·10	·11	·11	·10	·13	·12	·14
April	3·02	4·45	2·72	4·57	4·76	2·97	5·60	·73	·79	·62	·84	·86	·55	·93	·25	·35	·28	·34	·45	·32	·46
May	3·80	5·29	3·54	4·85	5·60	3·71	6·55	·46	·49	·45	·38	·43	·43	·33	·45	·48	·47	·61	·61	·38	·68
June	3·19	4·85	3·57	5·42	5·24	3·67	6·44	·26	·42	·39	·27	·27	·42	·27	·33	·38	·40	·51	·51	·34	·51
July	3·01	4·41	3·78	4·70	4·74	3·73	6·52	·36	·41	·42	·34	·32	·37	·19	·32	·35	·42	·49	·45	·35	·60
August	3·07	4·23	3·24	4·55	4·50	3·58	6·21	·60	·75	·66	·75	·64	·47	·73	·31	·33	·36	·44	·41	·40	·57
September	2·63	3·71	2·64	3·71	4·00	3·55	5·51	·79	1·00	·78	·99	1·08	·83	1·29	·18	·23	·22	·22	·32	·32	·39
October	1·89	2·60	1·88	2·65	2·70	2·49	4·07	·81	1·08	·75	1·01	1·10	·96	1·40	·09	·21	·11	·18	·13	·14	·17
November	1·24	1·76	1·28	1·53	1·63	1·38	2·40	·69	·86	·64	·73	·86	·69	1·04	·19	·26	·21	·23	·26	·21	·33
December	0·97	1·21	1·07	0·97	1·06	0·79	1·62	·62	·60	·61	·51	·56	·48	·75	·24	·28	·20	·15	·20	·21	·26
Mean 12 years	2·28	3·24	2·35	3·23	3·39	2·61	4·46	·61	·74	·60	·67	·72	·62	·84	·23	·29	·26	·30	·32	·27	·38

TABLE D (continued).—Mean Values of the Amplitude P, and of the First Maximum μ, reckoned from Local Apparent Midnight, for the First Three Orders of Harmonic Components of the Diurnal Inequality of Temperature at the Seven Observatories of the Meteorological Office, for each Month of the Year and for the entire Year, obtained from Twelve Years' Observations from 1871 to 1882.

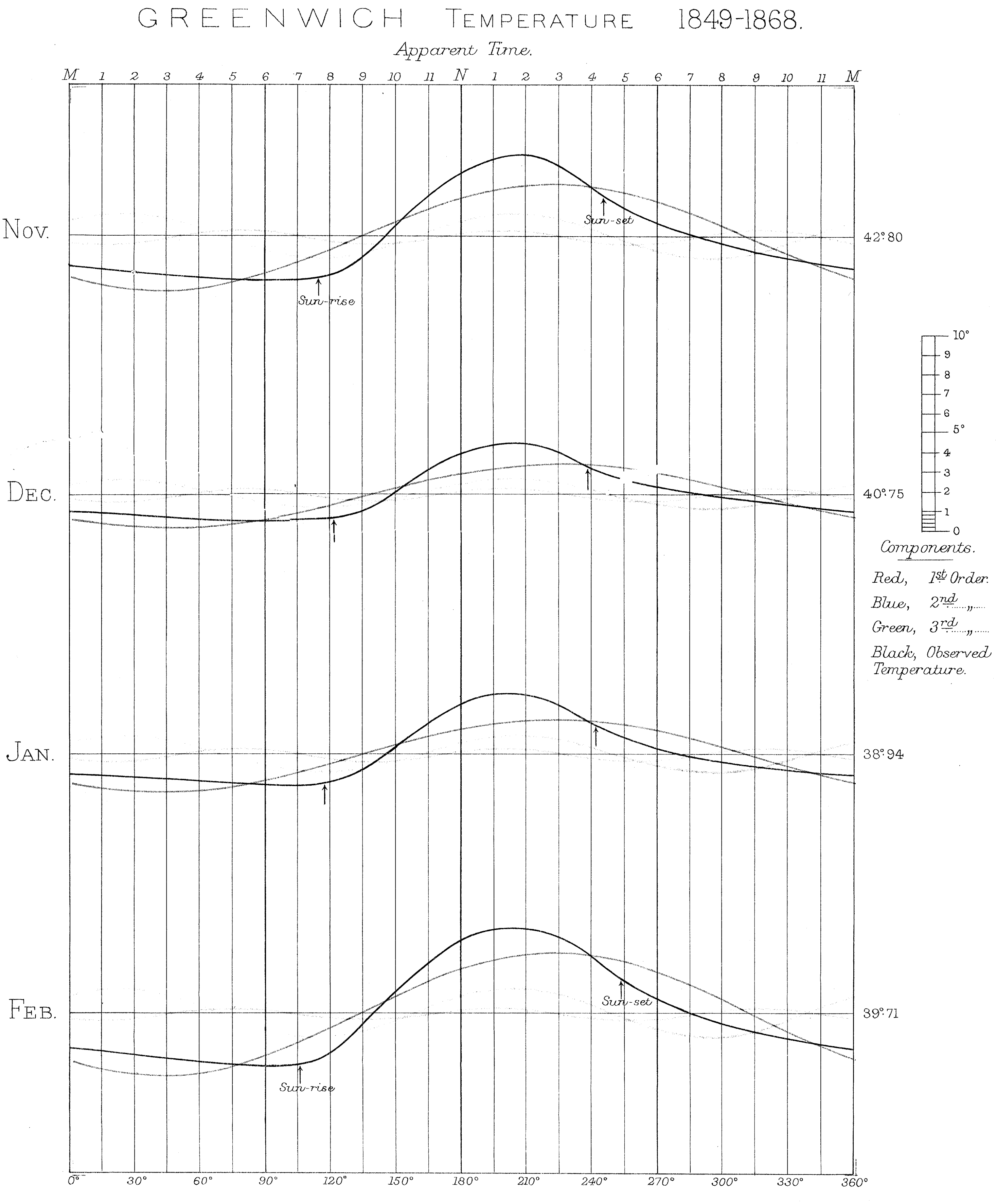
Months.	Valencia.	Armagh.	Falmouth.	Glasgow.	Stonyhurst.	Aberdeen.	Kew.
	μ_1.						
January	199°	220°	212°	222°	218°	215°	218°
February	206	215	209	220	216	215	221
March	208	214	207	217	216	211	223
April	211	213	207	218	213	208	219
May	208	213	205	217	211	206	220
June	204	211	201	213	210	203	219
July	203	212	200	211	210	205	220
August	203	213	202	213	213	208	220
September	204	215	205	215	213	211	219
October	204	212	208	220	213	214	220
November	203	220	209	220	216	216	221
December	204	220	205	231	225	202	219
Mean 12 years	205	215	206	218	215	210	220

Months.	Valencia.	Armagh.	Falmouth.	Glasgow.	Stonyhurst.	Aberdeen.	Kew.
	μ_2.						
January	17°	21°	12°	22°	22°	21°	25
February	13	18	10	21	20	18	25
March	15	15	10	18	18	15	24
April	16	9	8	19	16	1	19
May	13	3	−6	26	3	−35	8
June	17	−3	−1	26	−15	−44	5
July	14	5	−2	20	3	−36	1
August	15	13	5	19	14	−14	19
September	14	13	9	16	15	10	22
October	13	18	11	22	19	18	21
November	16	19	13	23	20	21	23
December	17	20	14	25	22	19	25
Mean 12 years	15	13	7	21	13	0	18

Months.	Valencia.	Armagh.	Falmouth.	Glasgow.	Stonyhurst.	Aberdeen.	Kew.
	μ_3.						
January	72°	73°	69°	78°	75°	76°	76°
February	69	70	61	77	74	72	83
March	28	40	34	30	37	39	23
April	10	21	16	18	18	19	19
May	12	15	13	13	16	9	17
June	11	13	10	14	15	5	17
July	9	15	11	11	14	9	17
August	11	18	13	15	15	14	18
September	15	28	20	21	20	23	21
October	67	65	57	74	67	61	58
November	67	72	66	76	72	76	75
December	77	73	70	84	75	75	79
Mean 12 years	37	42	37	43	42	40	42

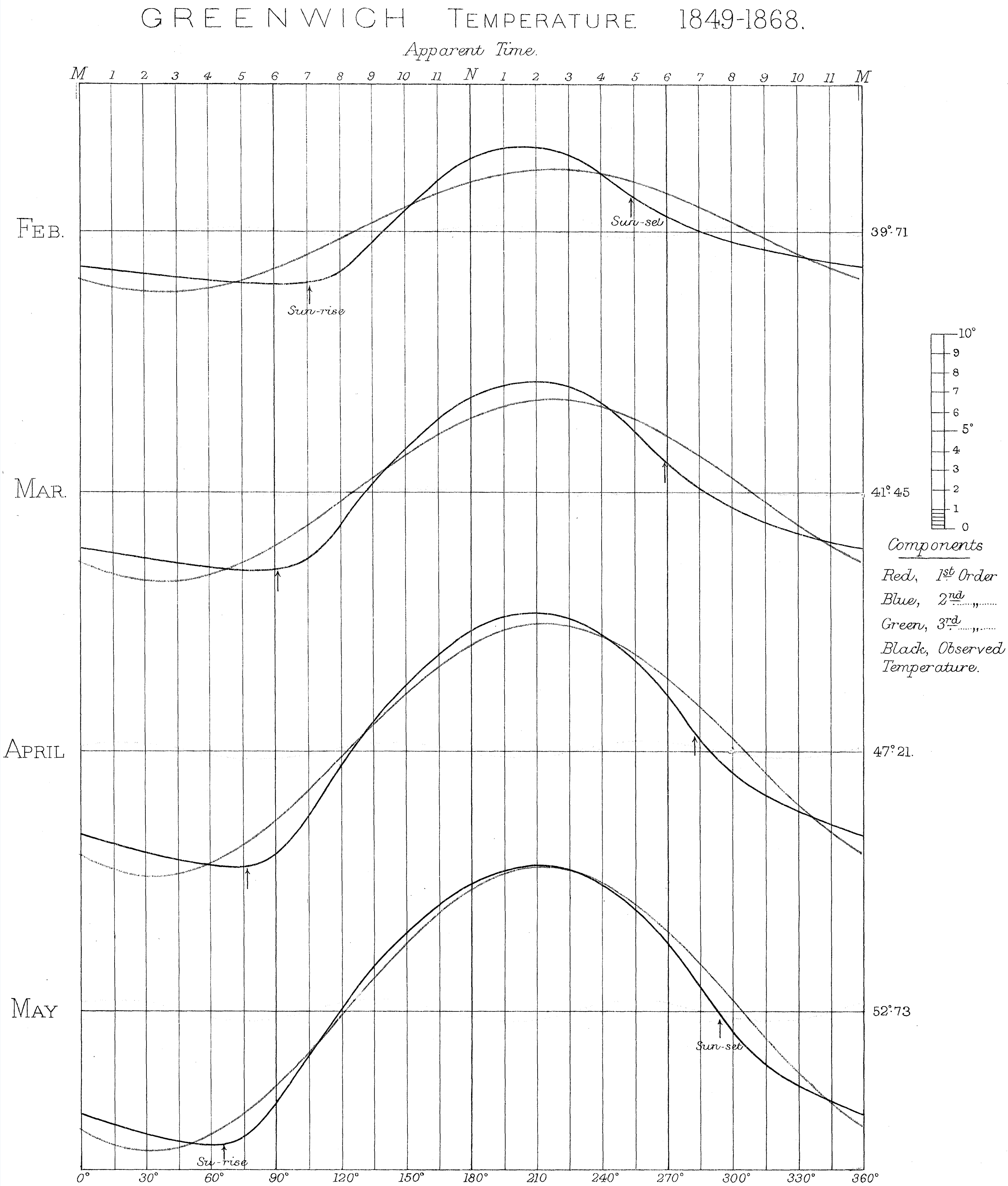
TABLE E.—Mean Monthly Values of the Equation of Time, the Sun's Declination and Right Ascension, and of the Apparent Time of Sun Rise, at Greenwich and at the Seven Observatories for each Month of the Year. The time is in Angular Measure.

		Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
Apparent time = mean time . . .		− 2° 25′	− 3° 31′	− 2° 1′	− 0° 2′	+ 0° 52′	− 0° 4′	− 1° 20′	− 0° 40′	+ 1° 26′	+ 3° 30′	+ 3° 35′	+ 0° 57′
Sun's declination		S. 20 38	S. 12 40	S. 1 4	N. 9 54	N. 17 38	N. 23 9	N. 21 8	N. 13 34	N. 2 45	S. 8 52	S. 18 30	S. 23 2
Sun's longitude.		296 0	326 0	356 0	26 0	55 0	85 0	114 0	143 0	173 0	203 0	234 0	265 0
Greenwich. Lat. 51° 29′ N. .	Sun rise A. T.	118 14	106 24	91 20	77 20	66 28	57 31	60 57	72 21	86 32	101 18	114 51	122 17
Long. 0° 0′ . .	,, merid. alt.	17 53	25 51	37 27	47 25	56 9	61 40	59 39	52 5	41 16	29 39	20 1	15 29
Kew. Lat. 51° 28′ N. .	,, rise A. T.	118 13	106 24	91 20	77 20	66 28	57 32	60 58	72 22	86 32	101 18	114 51	122 16
Long. 0° 19′ W. .	,, merid. alt.	17 54	25 52	37 28	47 26	56 10	61 41	59 40	52 6	41 17	29 40	20 2	15 30
Stonyhurst. Lat. 53° 51′ N. .	,, rise A. T.	121 1	104 9	91 28	76 11	64 13	54 11	58 3	70 43	86 14	102 20	117 15	125 35
Long. 2° 28′ W. .	,, merid. alt.	15 31	23 29	35 5	45 3	53 47	59 18	57 17	49 43	38 54	27 17	17 39	13 7
Falmouth. Lat. 50° 9′ N. .	,, rise A. T.	116 49	105 37	91 16	77 56	67 37	59 12	62 25	73 12	86 42	100 46	113 38	120 37
Long. 5° 4′ W. .	,, merid. alt.	19 13	27 11	38 47	48 45	57 29	63 0	60 59	52 25	42 36	30 59	21 21	16 49
Aberdeen. Lat. 57° 10′ N. .	,, rise A. T.	125 42	110 23	91 39	74 18	60 29	48 30	53 12	68 2	85 44	103 59	121 14	131 13
Long. 2° 6′ W. .	,, merid. alt.	12 12	20 10	31 46	41 44	50 28	55 59	53 58	46 24	35 35	23 58	14 20	9 48
Glasgow. Lat. 55° 53′ N. .	,, rise A. T.	123 46	109 23	91 35	75 4	62 1	50 52	55 13	68 8	85 26	103 19	119 36	128 52
Long. 4° 18′ W. .	,, merid. alt.	13 29	21 27	33 3	43 1	51 45	57 16	55 15	47 41	36 52	25 15	15 37	11 5
Armagh. Lat. 54° 21′ N. .	,, rise A. T.	121 40	108 16	91 29	75 55	63 42	53 25	57 23	70 20	86 10	102 34	117 49	126 21
Long. 6° 39′ W. .	,, merid. alt.	15 1	22 59	34 35	44 33	53 17	58 48	56 47	49 13	38 24	26 47	17 9	12 37
Valencia. Lat. 51° 55′ N. .	,, rise A. T.	119 43	106 40	91 22	77 8	66 4	56 56	60 27	72 4	86 29	101 29	115 17	122 52
Long. 10° 18′ W. .	,, merid. alt.	17 27	25 25	37 1	46 59	55 43	61 14	59 13	51 39	40 50	29 13	19 35	15 3



West, Newman, Chromo. lith.

GREENWICH TEMPERATURE 1849-1868.



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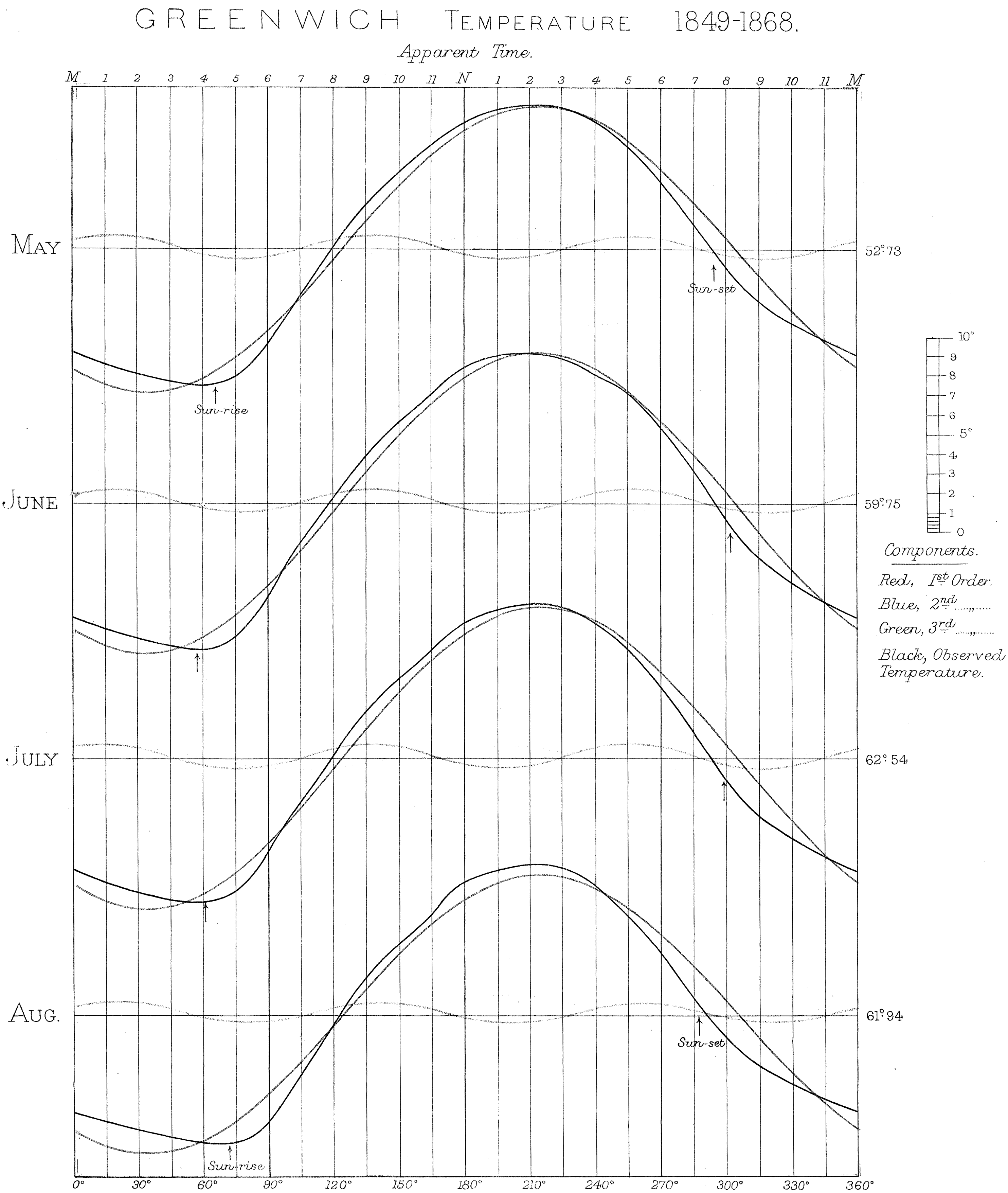
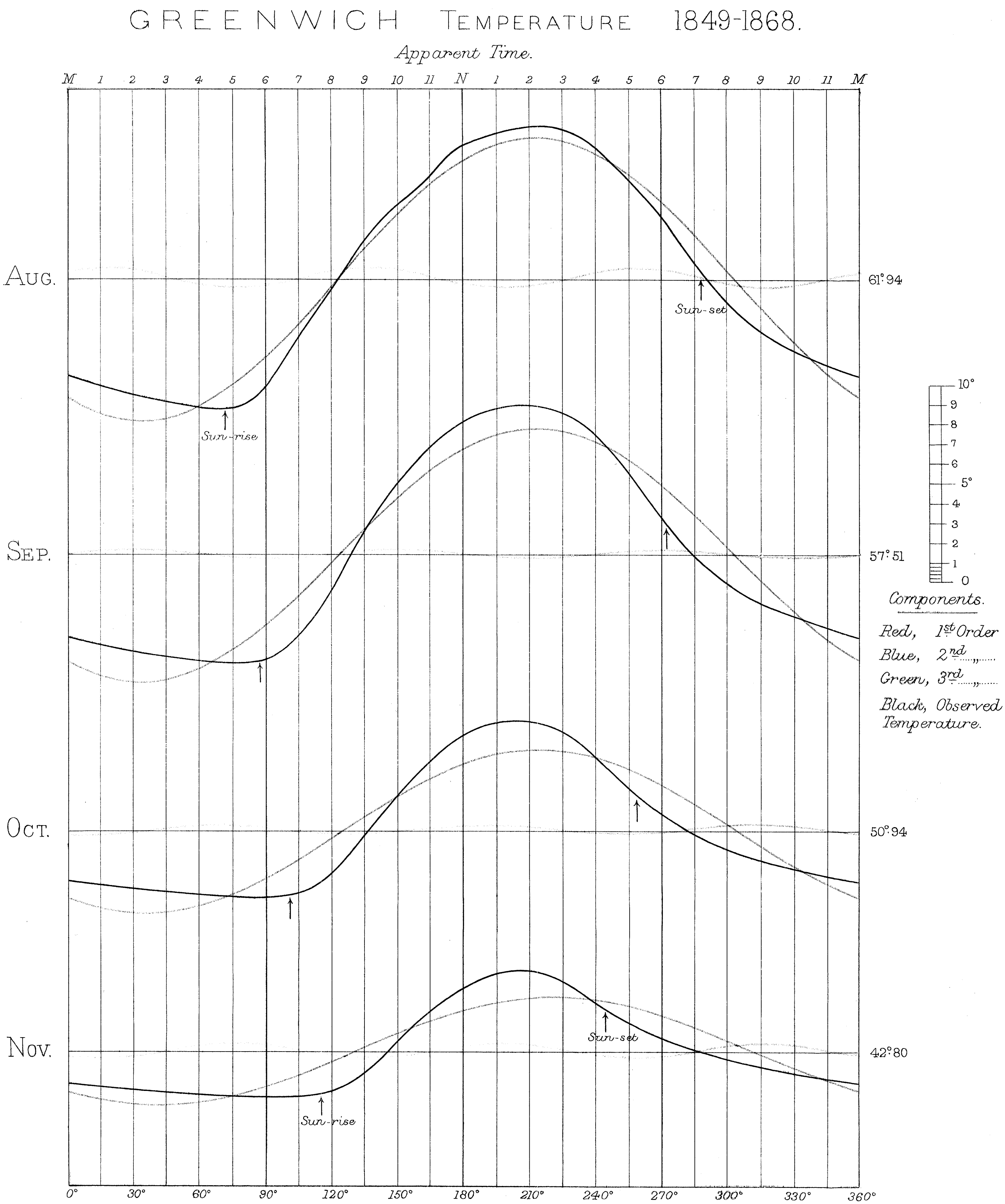


West, Newman, Chromo. lith.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES



West, Newman, Chromo lith.

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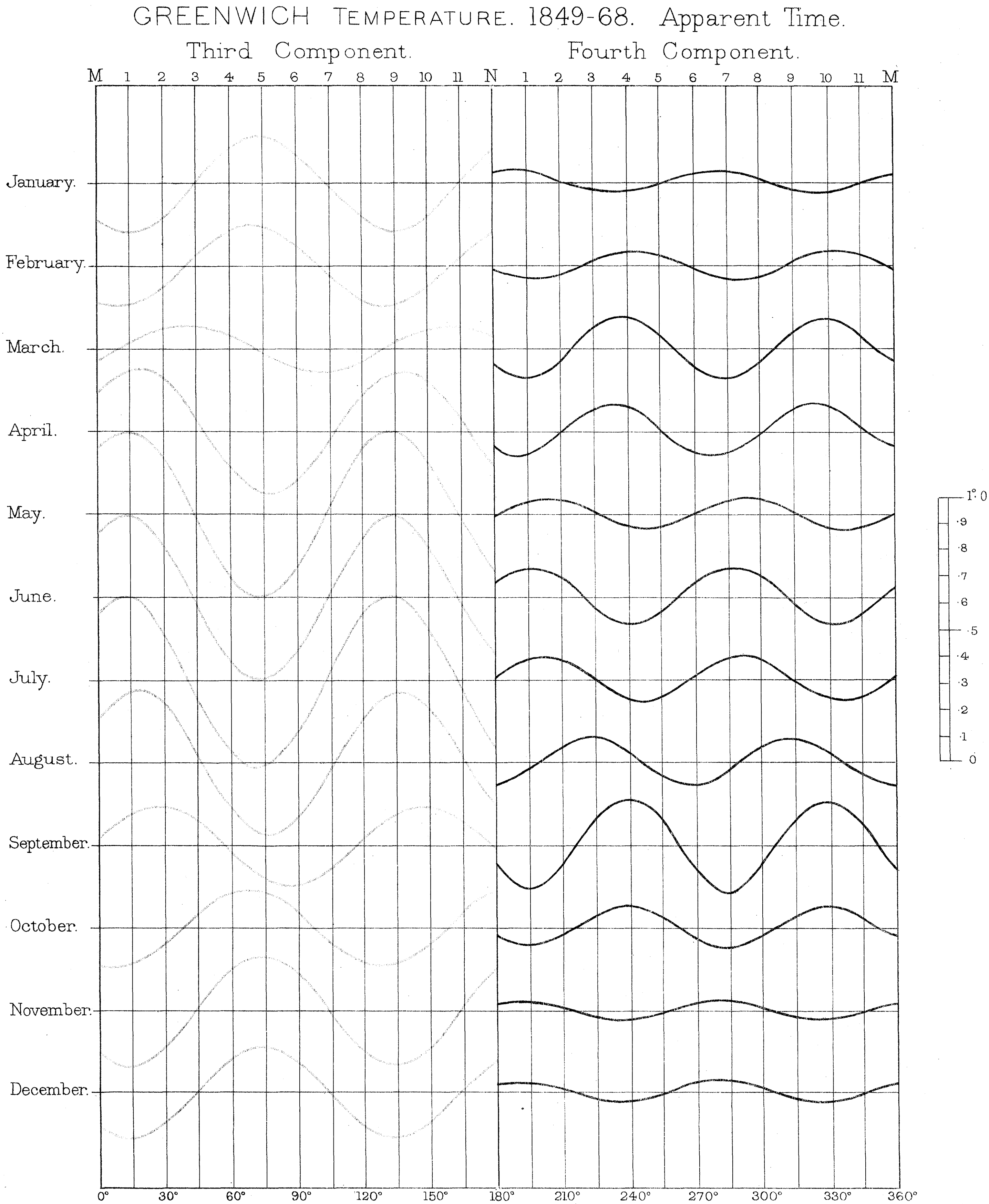
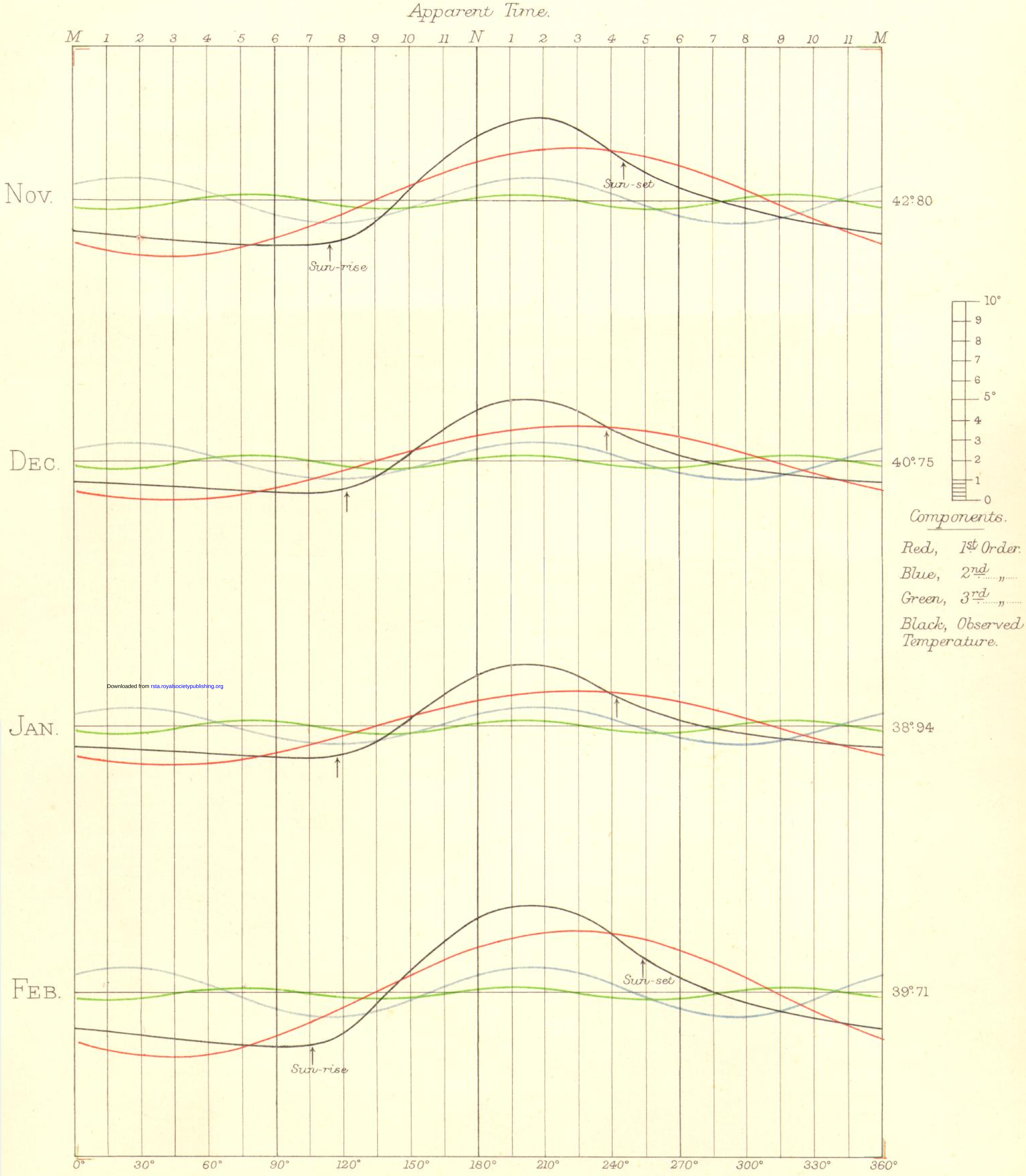


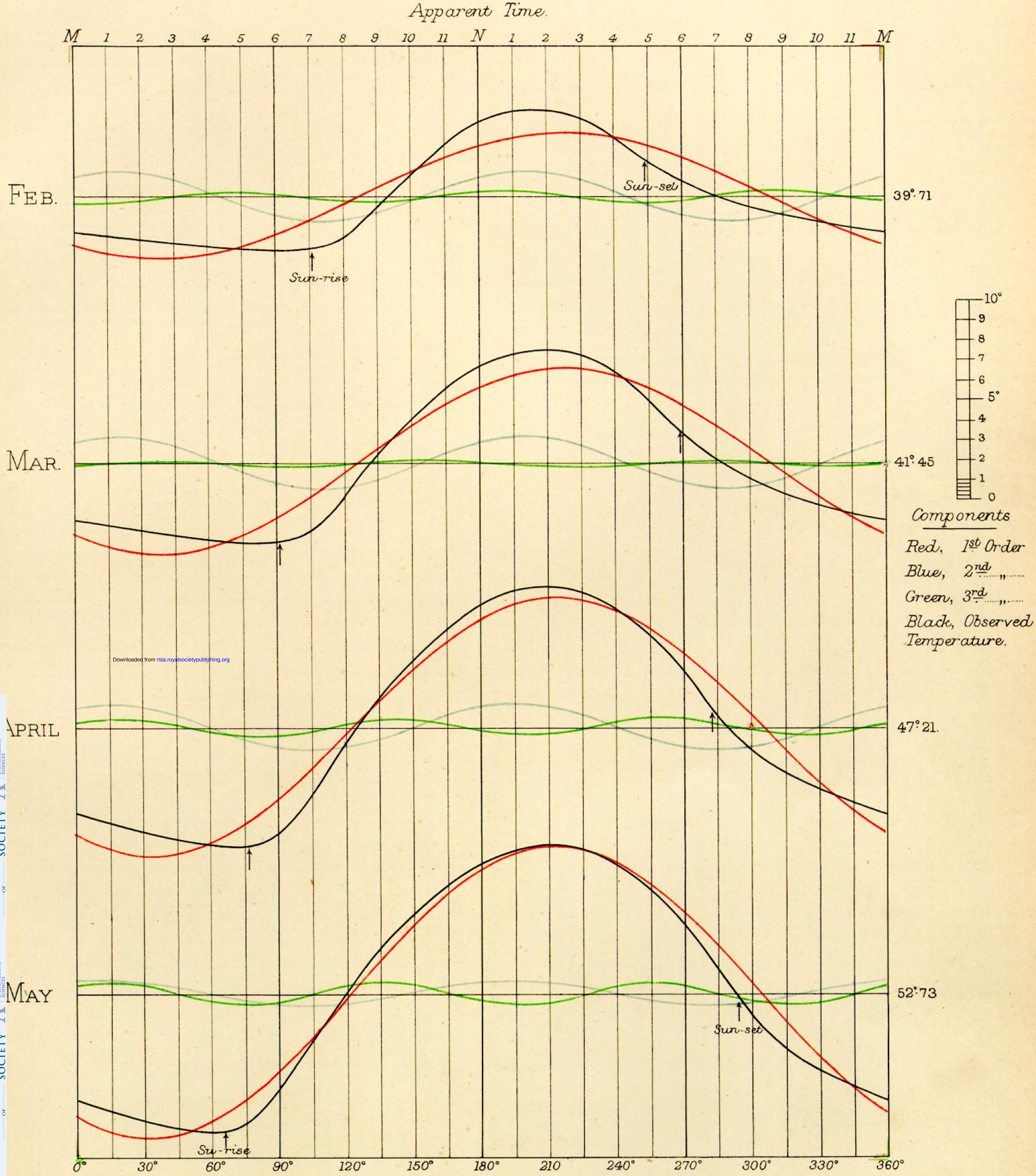
West, Newman, Chromo, lith.

GREENWICH TEMPERATURE 1849-1868.

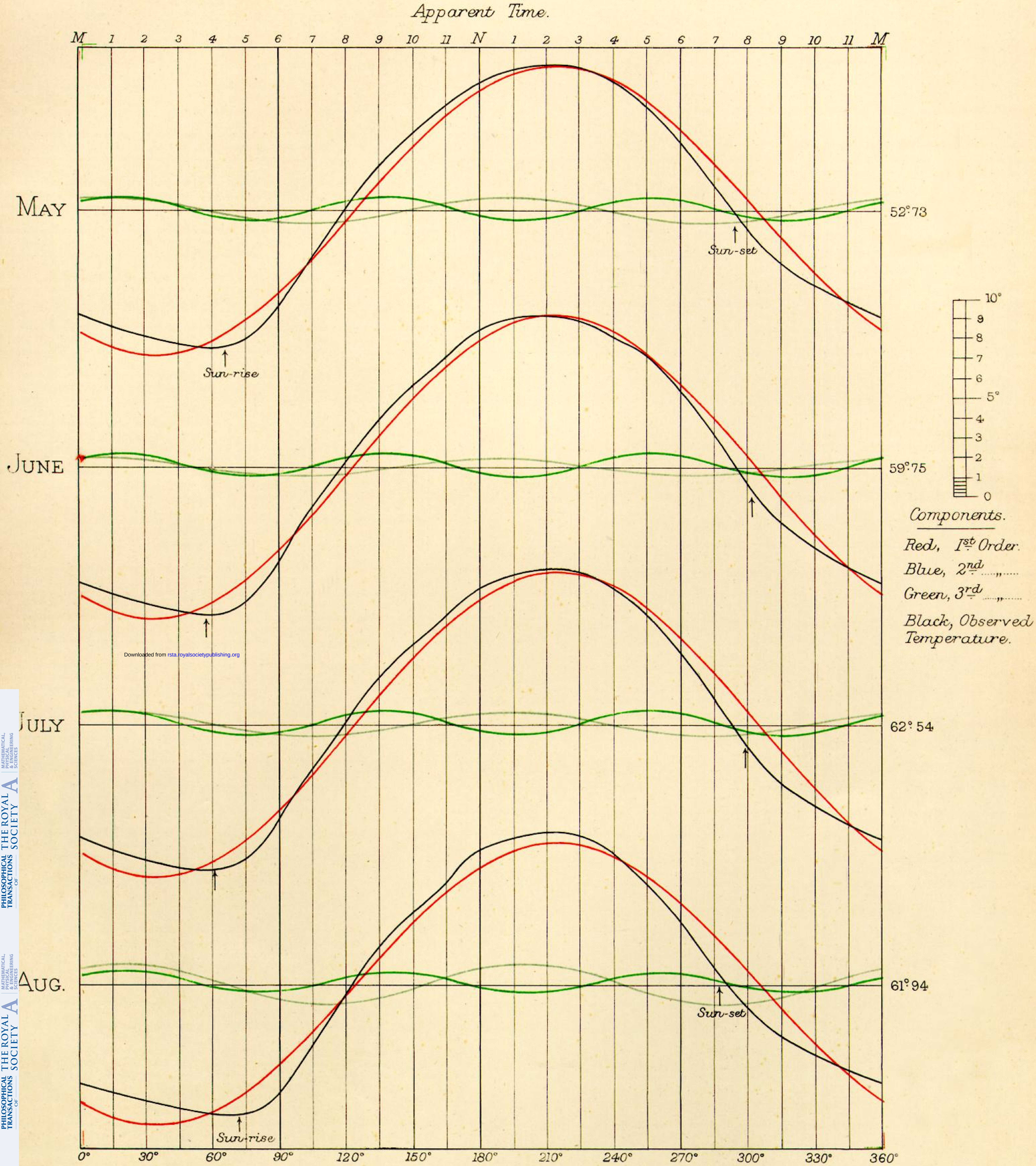


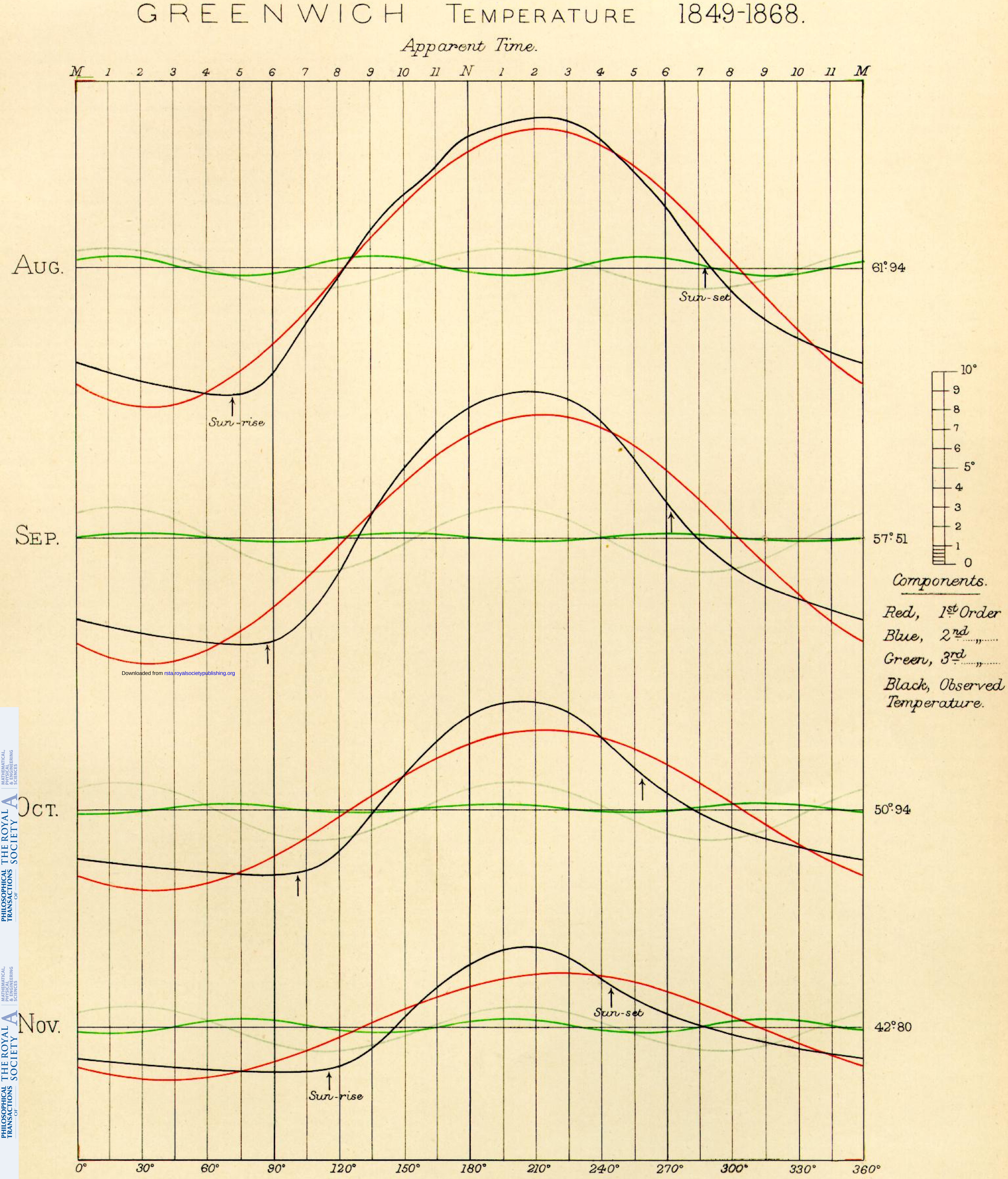
PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

GREENWICH TEMPERATURE 1849-1868.



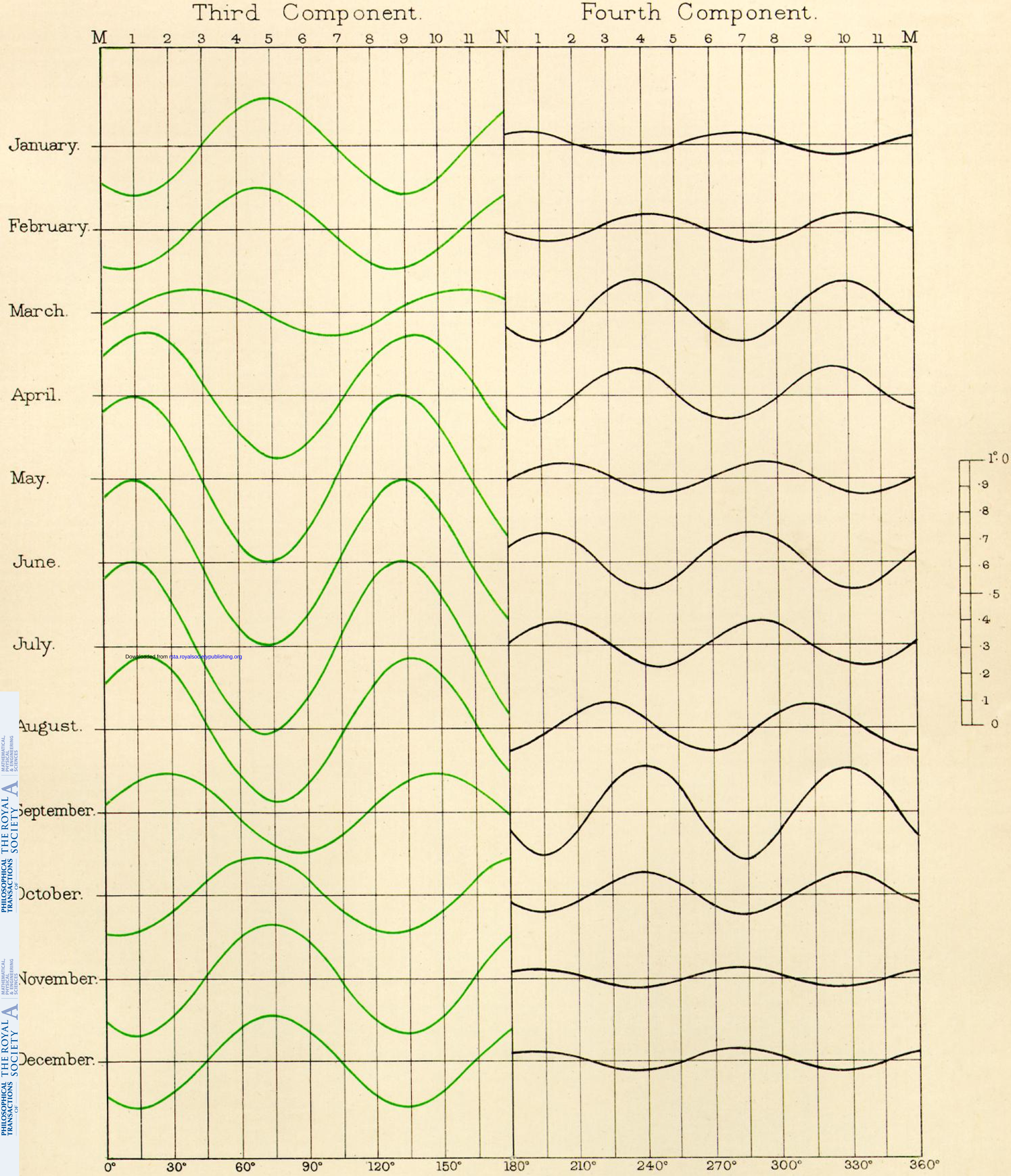
GREENWICH TEMPERATURE 1849-1868.





GREENWICH TEMPERATURE 1849-1868.
Apparent Time.
M 1 2 3 4 5 6 7 8 9 10 11 N 1 2 3 4 5 6 7 8 9 10 11 M
Aug.
61°.94
Sun-set
Sun-rise
Sep.
57°.51
Oct.
50°.94
Nov.
42°.80
Sun-set
Sun-rise
10°
9
8
7
6
5°
4
3
2
1
0
Components.
Red, 1st Order
Blue, 2nd "
Green, 3rd "
Black, Observed Temperature.
0° 30° 60° 90° 120° 150° 180° 210° 240° 270° 300° 330° 360°

GREENWICH TEMPERATURE. 1849-68. Apparent Time.



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