HELIOGRAPHIC POSITIONS OF SUN-SPOTS OBSERVED AT HAMILTON COLLEGE FROM 1860-1870

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Heliographic positions of sun-spots observed at Hamilton College from 1860-1870 by C. H. F. Peters & Edwin B. Frost

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C. H. F. PETERS & EDWIN B. FROST

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HELIOGRAPHIC POSITIONS OF SUN-SPOTS

OBSERVED AT HAMILTON COLLEGE

FROM 1860 TO 1870

BY

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EDITED FOR PUBLICATION
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EDWIN B. FROST

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INTRODUCTION

The observations now finally published in this volume were made by Professor Peters, during the decade beginning in 1860, with the 13-inch Spencer refractor of the Litchfield Observatory of Hamilton College, at Clinton,[1] N. Y. They were prepared in tabular form by their author for publication, and his 412 pages of manuscript tables, with some minor omissions, served the printer as copy. It is supposed that Dr. Peters also wrote an introduction describing the methods of observation and reduction, but unfortunately this seems to have been hopelessly lost. The fourteen original notebooks entitled, "Observationes astronomicae originales Maculae Solis," are preserved in good condition. These contain for each date a pencil sketch of the appearance of the spots on the sun's disk (of diameter about 11 cm), presumably copied from the larger sketch made on the projection screen. They also record the readings from the chronograph sheets and the declination scale, together with the clock error.

There were also preserved the 312 sheets of reductions, representing the logarithmic work involved in deriving the heliographic latitude and longitude. These also show what reduction quantities, calculated from the adopted elements of the sun's rotation, were used each day, but they do not state whence the elements were derived. The author doubtless computed tables for his own use in the work, but they have not been found. Investigation has shown that he employed for the longitude of the node and the inclination the values derived by Carrington from his long series of observations, and recommended by him for future adoption, viz., $N = 73° 40'$ for 1850, $I = 7° 15'$. Dr. Peters employed a different period and a different epoch from those of Carrington, and reckoned his longitudes in the opposite direction.

In order to give, in the author's own words, a general description of the procedure followed in the observations, the editor has translated the following article by Dr. Peters, which appeared in Band **64**, pp. 209–213 (1865), of *Astronomische Nachrichten*.

"In the observations which have been made here since May 1860 on the phenomena of the solar surface, the principle was adopted of measuring as far as possible everything of a measurable character that appeared on the solar disk. Therefore in the first instance the co-ordinates were determined of all the visible spots on each date, and these determinations were extended to all the isolated dots and the principal members of groups; also, indeed, to many faculae of definite form. For spots of considerable extent the dimensions of the umbra and penumbra were micrometrically determined, generally in the direction of declination and right ascension. An accurate sketch was always prepared before the observations and was a necessary auxiliary, partly for convenience as a reference map during the observations and partly for the comparative study both of the changes in the forms of the spots and the arrangements of the components of the groups, as well as of the intensity of the outbursts and their relative positions and sequence. In the winter months observations were made on every favorable day; but in summer, when fair weather can be more safely counted on, every second day was made the rule, inasmuch as this was in general sufficient for keeping the spots under watch in their different stages; and, moreover, the use of the refractor for the observations at night always required a somewhat disturbing exchange of the attachments at the eyepiece.

"For the observation of the sun the image was projected on a screen which, firmly attached to the refractor, shared in its motions. At the lower end of the large tube of the telescope two wooden rings were put on at some distance apart; each having four corresponding holes through which wooden rods, only slightly elastic, projected about one and a half feet. The projection board was fastened in notches cut in these rods at the same distance from the eyepiece, and was held in place by the springing of the rods. This not only assured the perpendicularity of the plane of projection with respect to the optical axis but it also prescribed that the distance of the plane of projection from the eyepiece was always the same when the latter was drawn out to a definite mark corresponding to the sharpest image. To the board was attached a rather stiff sheet of paper on which had been drawn two systems of parallel lines crossing each other at right angles. A single pin, passing through the center of these lines, attaches the paper at the point where the center of the image of the field of the telescope falls. By turning the sheet around the pin, the lines can thus be made parallel to the directions of declination and hour angle. It is only necessary for this purpose to let the sun's limb, or any distinct spot, run across parallel to one of the system of lines, preferably along

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[1] Latitude = 43° 3′ 17″
Longitude = $5^h\ 1^m\ 37^s.5$ W.

the central line. Since the angular distances from the center are projected toward the tangent, all points which transit describe hyperbolic curves. Thus we have a network of declination and time threads. For measuring differences of declination the central vertical line is graduated like a scale, and since the field of view permits the whole solar image to be seen, the scale-reading can be expressed in seconds of arc with the aid of the known apparent diameter of the sun. As one division has a linear value of $\frac{1}{8}$ inch (with an angular value of about 23″), the tenths, and sometimes the twentieths, can readily be estimated. The differences of right ascension are measured by the diurnal motion with the aid of a chronograph. In order to avoid a correction which would arise from the projection above mentioned upon the plane, the transits were so arranged that use was made either of the line passing through the center of the field or of symmetrically situated pairs of lateral threads.

"The eyepiece used is a so-called negative one of the Huyghens form, having two plano-convex lenses with focal lengths of 3.90 and 1.75 inches. The magnification is approximately 75, and the field of view is 38′, so that it embraces on each side 3′ more than the whole solar disk. The eyepiece is drawn out 1.45 inches in order to make the image distinctly visible at the distance of the projection board from the eye lens—15.43 inches. The actual magnification of the image is here about 140 times, or the number which we obtain if the magnification given above is multiplied by the quotient of the distance of the table divided by the distance of distinct vision (7 to 8 inches).

"Further explanation is required of the conversion of the scale-distance into arc whereby the distance in declination of a spot from the sun's center is measured. On account of the size of the angles under which the rays fall upon the paper, the tangents can no longer be held to be proportional to the arc, and the value of a scale-division decreases from the center of the field toward the edge. These angles have their vertex at the position for the eye; or rather, in this case, where the eyepiece is drawn out, in more general terms in the point through which all rays pass after emergence from the eyepiece, and therefore the distance of this point from the board is concerned. Instead of computing this from the dimensions of the system of lenses, we in practice get a knowledge of this most simply by pointing the telescope toward the brightly illuminated sky and rendering the emergent pencil visible (as by blowing smoke upon it). Let us denote this distance, expressed in scale-divisions, by D, the angle of the cone of the sun's disk formed at the intersection by G; g is similarly the angle at the same point between the spot and the sun's center, ρ is the apparent radius of the sun, S its magnitude read off from the table, s the distance of the spot from the sun's center. Then we have

$$\tan G=\frac{S}{D}, \quad \tan g=\frac{s}{D}, \quad \text{whence } \frac{s}{S}\frac{\tan G}{\tan g}=1\,;$$

therefore

$$\rho\frac{g}{G}=\rho\cdot\frac{s}{S}\cdot\frac{g}{G}\cdot\frac{\tan G}{\tan g}\,.$$

But the last is the difference in declination of the spot and the sun; therefore

$$\Delta\delta=\rho\frac{s}{S}\cdot\frac{\tan G}{G}\cdot\frac{g}{\tan g},$$

which is most conveniently adapted to calculation in the form

$$\log\Delta\delta=\log s+\log\frac{\rho}{S}+\frac{2}{3}\log\sec G-\frac{2}{3}\log\sec g\,.$$

A small table of double entry, with the arguments s and ρ, gives $\Delta\delta$ directly. For the apparatus here $D=119^{p}.0$, and on the average $G=19^\circ\,30'$. The diameter of the solar image measures somewhat over ten inches on the paper.

"The transits for right ascension are as a rule taken four times, twice before and twice after reading off the declinations, each time over one thread. When the number of spots is large, as has often been the case in recent years; and several groups fall at the same hour-angle, each section has to be determined for itself. The usefulness of the chronograph should be particularly recognized in such cases as this where the objects follow each other in rapid succession—often separated by only a fraction of a second. The clock is regulated to mean time so that the differences of right ascension are obtained without further reduction, since the departure of the rate from apparent solar time does not come into consideration, never exceeding $\frac{1}{3000}$. The accuracy obtained, as well as the simplicity of the reduction and the whole procedure will be the more readily perceived from the following example. The separate groups of each day are distinguished in order of right ascension by the capital letters, the separate spots of the groups in the same order by the small letters with the attached exponents; but the most conspicuous spot of each group is assigned the letter without an exponent; different nuclei in the same penumbra receive subscripts. This mode of designation is preferable to that of current numbers.

EXAMPLE

1863. March 13.

	CHRONOGRAPH READINGS		DECLINATION SCALE	CHRONOGRAPH READINGS		R. A. FROM SUN'S CENTER					DECLINATION	
	Set I	Set II	Divisions	Set III	Set IV	I	II	III	IV	Mean	Divisions	″
⊙ Limb	$0^h\,39^m\,11^s.4$	$41^m\,33^s.5$	+46.2	$0^h\,48^m\,28^s.4$	$0^h\,50^m\,57^s.1$	....	....	....	....	.....	+43.9	.....
A a	24.3	45.8	−20.7	40.9	51 9.6	$-51^s.7$	$-52^s.3$	$-52^s.2$	$-52^s.1$	$-52^s.05$	−23.0	−521
a^1	24.9	46.6	−20.8	41.8	10.4	51.1	51.5	51.4	51.3	51.3	−23.1	−523
B b	58.3	42 20.2	− 6.0	49 15.2	44.0	17.7	17.9	17.9	17.7	17.8	− 8.3	−190
C c	40 5.2	27.6	− 4.0	22.2	50.9	10.8	10.5	11.0	10.8	10.8	− 6.3	−144
d	7.6	29.5	+ 0.4	24.6	53.3	8.4	8.6	8.5	8.4	8.45	− 2.0	− 45
d^1	9.8	31.9	+ 0.7	26.8	55.5	6.2	6.2	6.3	6.2	6.2	− 1.6	− 37
$D\,d^2$	10.2	32.3	+ 1.9	27.3	56.0	5.8	5.8	5.8	5.7	5.75	− 0.4	− 9
d^3	11.9	34.0	+ 1.4	28.8	57.5	4.1	4.1	4.3	4.2	4.15	− 0.9	− 21
d^4	14.0	36.2	+ 0.6	31.1	59.6	2.0	1.9	2.0	2.2	2.0	− 1.7	− 39
e^1	28.3	50.3	+ 3.6	45.2	52 13.8	+12.3	+12.3	+12.1	+12.1	+12.2	+ 1.3	+ 30
$E\,e^2$	29.0	51.2	+ 3.0	46.0	15.0	13.0	13.1	12.9	13.3	13.1	+ 0.7	+ 16
e	32.7	54.6	+ 1.0	49.8	18.5	16.7	16.6	16.7	16.8	16.7	− 1.3	− 30
Penumbra	41 3.5	43 25.0	+30.3	....	49.2	47.7	47.0	....	47.5	47.3	+28.0	+631
F Center	4.2	25.7	+29.8	50 20.9	49.9	48.2	47.7	47.7	48.2	47.95	+27.5	+620
Penumbra	5.0	26.8	+29.3	....	50.7	49.0	48.7	....	49.0	48.85	+27.0	+609
⊙ Limb	20.6	42.7	−41.6	37.9	53 6.3	....	....	....	....	....	−43.9	....
⊙ Center	$0^h\,40^m\,15^s.97$	$0^h\,42^m\,38^s.05$	+ 2.3	$0^h\,49^m\,33^s.13$	$0^h\,52^m\,1^s.7$	$64^s.58$	$64^s.60$	$64^s.78$	64.60	$64^s.64$		

"The mean of the times is $0^h\,46^m\,7^s.2$, and the correction of the clock $+8^s.5$, so that the observations as taken are valid for $0^h\,46^m\,15^s.7$ mean time.

"The probable error of an observation was deduced to be $\pm 0^s.11$ from a number of determinations of the time of transit of the sun's radius, by means of the deviations from the average of each day. For a spot the error in general will be somewhat greater; and since on the one hand this has to be multiplied by a number larger than $\sqrt{2}$, while on account of being the average of four determinations, it must on the other hand be divided by 2, we may estimate the accuracy of the determination as $1'.5$. The probable error in declination will be about the same, since here the limit of reading is from $\frac{1}{20}$ to $\frac{1}{10}$ of a scale-division."

The formulae now involved are simply derived by applying the three fundamental formulae of spherical trigonometry to the triangle having as its vertices the spot, the sun's pole and the center of the disk.

Let $\Delta\alpha$ and $\Delta\delta$ represent the differences in right ascension and declination of the spot and the center of the disk. Let p be the "zenith distance of the earth as seen from the spot," and n be the geocentric distance of the spot from the center of the disk. Then $n=\rho \sin p$, where ρ is the sun's radius. P is the symbol for the position angle of the spot, reckoned from the east through the north, and N is the position angle of the sun's pole. B is the heliographic latitude of the spot, B_0 that of the center of the disk; L and L_0 are the heliographic longitudes of the spot and of the center of the disk from the node.

Then we have

$$\frac{\Delta\alpha''}{\rho}=\sin p \cos P\,;$$

$$\frac{\Delta\delta''}{\rho}=\sin p \sin P\,.$$

$$\sin B=\cos(p-n)\sin B_0+\cos B_0 \sin(p-n)\sin(P-N)\,;$$

$$\cos B\cos(L-L_0)=\cos(p-n)\cos B_0-\sin B_0\sin(p-n)\sin(P-N)\,;$$

$$\cos B\sin(L-L_0)=\sin(p-n)\cos(P-N)\,.$$

For adaptation to logarithmic computation, let

$$g\sin\zeta=\sin(p-n)\sin(P-N)\,,$$

$$g\cos\zeta=\cos(p-n)\,.$$

Then we get

$$\sin B=g\sin(B_0+\zeta)\,;$$

$$\cos(L-L_0)\cos B=g\cos(B_0+\zeta)\,;$$

$$\sin(L-L_0)\cos B=\sin(p-n)\cos(P-N)\,.^{[1]}$$

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[1] It seems that it would have been more expeditious to use addition and subtraction logarithms and employ the first and third of the fundamental formulae, solving $(L-L_0)$ by the tangent only when necessary.

An example of the author's reduction sheet now follows:

March 13, 1863. $0^h\ 46^m$ Clinton Mean Time

(1)	(2) $lg\Delta\alpha$	(3) $lg\Delta\delta$	(4) $\sin p \sin P$	(5) $\sin p \cos P$	(6) sin or cos P	(7) P	(8) $\sin p$	(9) $\frac{\sin(p-n)}{\sin p}$	(10) $P-N$	(11) $\cos(P-N)$
a	1.7164*n*	2.7168*n*	9.7304*n*	9.9055*n*	9.9198	213° 45′	9.9856	− 5	189° 21′	9.9942*n*
a^1	1.7101*n*	2.7185*n*	9.7321*n*	9.8992*n*	9.9173	214 14	9.9818	5	189 50	9.9936*n*
b	1.2504*n*	2.2788*n*	9.2924*n*	9.4395*n*	9.9108	215 29	9.5287	19	191 5	9.9918*n*
c	1.0334*n*	2.1584*n*	9.1720*n*	9.2225*n*	9.8733	221 40	9.3492	20	197 16	9.9799*n*
d	0.9269*n*	1.6532*n*	8.6668*n*	9.1160*n*	9.9742	199 34	9.1418	20	175 10	9.9984*n*
d^1	0.7924*n*	1.5682*n*	8.5818*n*	8.9815*n*	9.9680	201 43	9.0135	20	177 19	9.9995*n*
d^2	0.7597*n*	0.9542*n*	7.9678*n*	8.7488*n*	9.9976	185 58	8.9511	20	161 34	9.9771*n*
d^3	0.6180*n*	1.3222*n*	8.3358*n*	8.8071*n*	9.9765	198 40	8.8306	20	174 16	9.9978*n*
d^4	0.3010*n*	1.5911*n*	8.6074*n*	8.4901*n*	9.8993	232 28	8.7054	20	208 4	9.9457*n*
e^1	1.0864	1.4771	8.4907	9.2755	9.9942	9 19	9.2813	20	344 55	9.9848
e^2	1.1173	1.2041	8.2177	9.3064	9.9986	4 40	9.3078	20	340 16	9.9737
e	1.2227	1.4771*n*	8.4007*n*	9.4118	9.9969	353 10	9.4149	20	328 46	9.9320
f	1.6808	2.7924	9.8060	9.8699	9.8791	40 48	9.9908	4	16 24	9.9820
	8.1891	7.0136				−24° 24′	2.9864			
	$lg\frac{15\cos\delta}{\rho}$	$lg\frac{1}{\rho}$				N	$lg\,\rho$			

(1)	(12) $\sin(p-n)$	(13) $\sin(P-N)$	(14) (12)+(13) $\equiv g\sin\zeta$	(15) $\cos(p-n)$ $\equiv g\cos\zeta$	(16) $\cos\zeta$	(17) ζ	(18) $B_0+\zeta$	(19) $\sin(B_0+\zeta)$	(20) $lg\,g$	(21) $\cos(B_0+\zeta)$
a	9.9851	9.2108*n*	9.1959*n*	9.4102	9.9312	−31° 24′	−38° 34′	9.7949*n*	9.4790	9.8931
a^1	9.9813	9.2324*n*	9.2137*n*	9.4583	9.9390	−29 39	−36 49	9.7776*n*	9.5193	9.9034
b	9.5268	9.2838*n*	8.8106*n*	9.9739	9.9990	− 3 56	−11 6	9.2845*n*	9.9749	9.9918
c	9.3472	9.4727*n*	8.8199*n*	9.9890	9.9990	− 3 52	−11 2	9.2822*n*	9.9900	9.9919
d	9.1398	8.9256	8.0654	9.9958	0.0000	+ 0 40	− 6 30	9.0539*n*	9.9958	9.9972
d^1	9.0115	8.6704	7.6819	9.9977	0.0000	+ 0 16	− 6 53	9.0791*n*	9.9977	9.9968
d^2	8.9491	9.5000	8.4491	9.9983	9.9998	+ 1 37	− 5 33	8.9855*n*	9.9985	9.9980
d^3	8.8285	8.9996	7.8281	9.9990	0.0000	+ 0 23	− 6 47	9.0723*n*	9.9990	9.9969
d^4	8.7033	9.6726*n*	8.3759	9.9994	9.9999	− 1 22	− 8 32	9.1714*n*	9.9995	9.9952
e^1	9.2793	9.4153*n*	8.6946*n*	9.9920	9.9994	− 2 53	−10 3	9.2418*n*	9.9925	9.9933
e^2	9.3058	9.5285*n*	8.8343*n*	9.9909	9.9989	− 3 59	−11 9	9.2864*n*	9.9919	9.9917
e	9.4129	9.7148*n*	9.1277*n*	9.9849	9.9958	− 7 54	−15 4	9.4151*n*	9.9891	9.9848
f	9.9904	9.4508	9.4412	9.3179	9.9025	+53 1	+45 51	9.8559	9.5387	9.8429
						−7° 10′				
						B_0				

(1)	(22) $\sin(p-n)\times$ $\cos(P-N)$	(23) $g\cos(B_0+\zeta)$	(24) $\sin(L-L_0)$ or $\cos(L-L_0)$	(25) $L-L_0$	(26) $g\sin(B_0+\zeta)$ $\equiv\sin B$	(27) $\cos B$	(28) B	(29) L	(30) L'	(31) Mar. 12	(32) Mar. 14
a	9.9793*n*	9.3721	9.9871	−76° 7′	9.2739*n*	9.9922	−10° 50′	185° 1′	6° 5′	a	—
a^1	9.9749*n*	9.4227	9.9836	74 20	9.2969*n*	9.9913	−11 26	186 48	7 52	a^3	—
b	9.5186*n*	9.9667	9.9740	19 37	9.2594*n*	9.9927	−10 28	241 31	62 35	c	σ
c	9.3271*n*	9.9819	9.9896	12 29	9.2722*n*	9.9923	−10 47	248 39	69 43	d	b
d	9.1382*n*	9.9930	9.9958	7 57	9.0497*n*	9.9972	− 6 26	253 11	74 15	e	c_1c_2
d^1	9.0110*n*	9.9945	9.9977	5 56	9.0768*n*	9.9968	− 6 51	255 12	76 16	σ	σ
d^2	8.9262*n*	9.9965	9.9984	4 52	8.9840*n*	9.9981	− 5 32	256 16	77 20	e^2	c^2
d^3	8.8263*n*	9.9959	9.9990	3 52	9.0713*n*	9.9969	− 6 46	257 16	78 20	e^3	c^3
d^4	8.6490*n*	9.9947	9.9996	2 35	9.1709*n*	9.9951	− 8 32	258 33	79 37	σ	..
e^1	9.2641	9.9858	9.9923	+10 45	9.2343*n*	9.9935	− 9 53	271 53	92 57	f^1	d^1?
e^2	9.2795	9.9836	9.9917	11 11	9.2783*n*	9.9919	−10 57	272 19	93 23	f^2	d^2
e	9.3449	9.9739	9.9883	13 13	9.4042*n*	9.9856	−14 41	274 21	95 25	f	d
f	9.9724	9.3816	9.9861	75 37	9.3946	9.9862	+14 22	336 45	157 49	—	e
				261° 8′				181° 4′			
				L_0				−178 56			
								long. of prime meridian from node			

The scheme of computation explains itself. In the ninth column the author sometimes gives n and sometimes $\frac{\sin(p-n)}{\sin p}$, for either of which a table with argument $\sin p$ could easily have been constructed. The elements of the sun's rotation, as employed by the author, are:

Longitude of the ascending node of sun's equator = 73° 40′ for 1850.
Inclination of axis to axis of ecliptic = 7° 15′.
(These were the values recommended by Carrington.)
Mean daily rotation angle = 842′.04 = 14°.034,
or Mean sidereal rotation period = 25.652 days.

This value was derived by Dr. Peters from his observations of 803 positions of 286 spots made at Naples in the thirteen months from September 1845 to October 1846, as stated in his paper read at the Providence meeting of the American Association, 1855.

"First solar meridian that in which the earth was at Greenwich mean noon 1860 January 0."

"I reckon the longitudes in the sense that any point of the heavens would, as a result of the sun's rotation, successively pass increasing meridians. This would correspond on the earth to counting longitudes westward as positive" (*A. N.*, **71**, 241, 1868).

"To avoid ambiguity, it may be prefaced that the heliographical longitudes are counted in the direction opposite to that of the rotation of the sun (or what corresponds upon the earth from the east toward the west), and a spot is said to be *following* another neighboring one, when the former has greater heliographical longitude,—when by the rotation of the sun, it will come later into the same heliocentric position in regard to the fixed stars than the *preceding* spot." (*Astronomical Notices*, No. 29, March 18, 1862.)

In order to facilitate the comparison of longitudes given by Peters with those of Carrington and those at Kew and at Greenwich, a conversion-table is given for each date of observation by Peters. A rigorous comparison cannot be made with Carrington's positions, as the latter were derived from assumed values of the longitude of the node and inclination, to which small corrections were obtained by Carrington from his whole series of observations. The difference is not, however, of any consequence in the identification of spots.

The following table, which has been calculated by Mr. Philip Fox, gives the angular distances between the prime meridians of the systems of Carrington and Peters for Clinton noon of each day when Peters observed. The conversion is effected by merely subtracting Peters' L' from the tabular value for the date (increased by 360° where necessary), after due allowance has been made for the difference in time of observation and in longitude of the place of observation.

TABLE OF ANGULAR DISTANCES BETWEEN THE PRIME MERIDIANS OF PETERS AND CARRINGTON
For Clinton noon of each day on which Peters observed.

1860			July	11	206°.02	Sept.	25	194°.59	Dec.	15	182°.40
May	23	213°.39		15	205.41		26	.44		23	181.20
	24	.24		18	204.96		28	.13			
	25	.08		20	.66		30	193.83	1861		
	29	212.48		22	.36	Oct.	6	192.93	Jan.	2	179°.70
June	3	211.73		24	.06		7	.78		4	.39
	4	.58		28	203.46		10	.33		5	.25
	5	.43		30	.16		12	.03		12	178.19
	6	.28		31	.01		15	191.58		22	176.69
	11	210.53	Aug.	1	202.86		16	.43		23	.54
	12	.38		3	.56		18	.13		25	.24
	13	.23		5	.26		19	190.98		27	175.94
	14	.08		6	.11		24	.22	Feb.	1	.18
	15	209.93		11	201.35		25	.07		6	174.43
	16	.78		15	200.75		27	189.77		12	173.53
	17	.63		16	.60		30	.32		14	.23
	18	.48		17	.45		31	.17		16	172.93
	19	.33		18	.30	Nov.	4	188.57		22	.02
	20	.17		19	.15		5	.42		25	171.57
	27	208.12		20	.00		7	.12		26	.42
	28	207.97	Sept.	15	196.09		8	187.97		27	.27
	30	.67		17	195.79		16	186.76		28	.12
July	4	.07		18	.64		22	185.86	Mar.	4	170.52
	6	206.77		20	.34		24	.56		7	.07
	7	.62		22	.04		25	.41		11	169.47
	8	.47		23	194.89		28	184.96		15	168.87
	9	.32		24	.74	Dec.	14	182.55		16	.72

	1861	
Mar.	18	168°.42
	19	.27
	20	.11
	22	167.81
	23	.66
	25	.36
	28	166.91
	31	.46
Apr.	4	165.86
	5	.71
	6	.56
	7	.41
	8	.26
	9	.11
	10	164.96
	11	.81
	19	163.60
	21	.30
	22	.15
	23	.00
	25	162.70
	26	.55
	27	.40
	29	.10
May	2	161.65
	4	.35
	5	.20
	7	160.89
	9	.59
	12	.14
	14	159.84
	15	.69
	19	.09
	21	158.79
	23	.49
	25	.19
	30	157.44
	31	.28
June	1	.13
	5	156.53
	7	.23
	9	155.93
	10	.78
	12	.48
	13	.33
	17	154.73
	18	.58
	20	.28
	22	153.98
	24	.68
	25	.53
	27	.22
	29	152.92
July	1	.62
	3	.32
	5	.02
	7	151.72
	9	.42
	11	.12
	17	150.22
	19	149.92
	21	.62
	23	.31
	25	.01
July	27	148°.71
Aug.	1	147.96
	3	.66
	4	.51
	11	146.46
	14	.01
	16	145.70
	18	.40
	19	.25
Sept.	7	142.40
	9	.09
	12	141.64
	15	.19
	22	140.14
	24	139.84
	26	.54
	29	.09
Oct.	1	138.79
	8	137.73
	10	.43
	12	.13
	14	136.83
	20	135.93
	21	.78
	25	.18
	26	.03
	27	134.87
	28	.72
	29	.57
Nov.	1	.12
	10	132.77
	12	.47
	14	.17
	15	.02
	18	131.57
	19	.42
	20	.27
	22	130.96
	24	.66
	25	.51
	26	.36
	27	.21
Dec.	2	129.46
	3	.31
	4	.16
	5	.01
	7	128.71
	10	.26
	11	.11
	12	127.96
	13	.81
	14	.66
	15	.51
	16	.36
	17	.20
	22	126.45
	25	.00
	28	125.55
	30	.25
	31	.10
	1862	
Jan.	2	124°.80
	3	.65
Jan.	4	124°.50
	7	.05
	11	123.45
	13	.14
	14	122.99
	16	.69
	24	121.49
	27	.04
	31	120.44
Feb.	5	119.68
	7	.38
	8	.23
	11	118.78
	16	.03
Mar.	8	115.02
	9	114.87
	11	.57
	13	.27
	18	113.52
	19	.37
	20	.22
	25	112.47
	26	.31
	27	.16
	28	.01
	29	111.86
Apr.	4	110.96
	6	.66
	7	.51
	9	.21
	10	.06
	11	109.91
	12	.76
	13	.61
	20	108.55
	22	.25
	24	107.95
	25	.80
	26	.65
	27	.50
May	4	106.45
	5	.30
	6	.15
	8	105.85
	10	.55
	11	.40
	12	.25
	14	104.95
	15	.79
	17	.49
	20	.04
	22	103.74
	24	.44
	26	.14
	28	102.84
	30	.54
June	5	101.64
	8	.18
	20	99.38
	22	.08
	26	98.48
	29	.03
July	1	97.73
	3	.43
	6	96.97
July	7	96°.82
	8	.67
	10	.37
	11	.22
	13	95.92
	15	.62
	18	.17
	19	.02
	25	94.12
	27	93.81
	29	.51
	31	.21
Aug.	2	92.91
	4	.61
	6	.31
	8	.01
	10	91.71
	12	.41
	14	.11
	15	90.96
	17	.66
	18	.51
	20	.21
	22	89.91
	24	.60
	26	.30
	29	88.85
	31	.55
Sept.	3	.10
	5	87.80
	7	.50
	9	.20
	11	86.90
	13	.60
	15	.30
	17	85.99
	19	.69
	21	.39
	23	.09
	25	84.79
	27	.49
Oct.	3	83.59
	5	.29
	7	82.99
	12	.23
	15	81.78
	18	.33
	20	.03
	23	80.58
	28	79.83
	31	.38
Nov.	2	.08
	4	78.77
	11	77.72
	14	.27
	15	.12
	25	75.62
	30	74.86
Dec.	5	.11
	8	73.66
	11	.21
	12	.06
	17	72.31
	20	71.86