GREENWICH OBSERVATIONS OF THE HORIZONTAL AND VERTICAL DIAMETERS OF THE SUN

P. J. D. Gething

(Communicated by the Astronomer Royal)

(Received 1955 June 17)

Summary

It has been claimed that the Greenwich observations of the horizontal diameter of the Sun are in agreement with those made at Campidoglio and Monte Mario in indicating a real variation of diameter with a period of about 22 years. It is shown in the present paper that this conclusion cannot be justified from the data considered. A more detailed analysis of the Greenwich measurements of both the horizontal and vertical diameters in the period 1915 to 1936 is given, in which corrections are applied for irradiation and personality differences between observers. The resulting diameters show comparatively large variations from year to year. These variations do not necessarily represent real changes in the size of the Sun; they may be due to variations in the mean personality correction. No definite relationship can be established between the apparent variations in diameters and other phenomena, such as the sunspot cycle.

---

1. *Introduction.*—Numerous authors claim to have detected variations in the diameter of the Sun, whereas other investigators, such as Auwers (**1**), failed to find any variation, or to detect any significant difference between the equatorial and polar diameters. The results of various series of observations have not been in good agreement, some authors finding an eight-year period, others an eleven-year period and others a twenty-two-year period, while estimates of the amplitude of the fundamental oscillation have ranged from a few hundredths to a few tenths of a second of arc, with extreme ranges of up to two seconds. Some authors (**1–4**) have examined heliometer measurements of the polar and equatorial diameters and others (**5–7**) the horizontal diameters at transit. Poor (**8**) has discussed measurements of photographic plates.

The series of measurements made with the transit circle at Campidoglio (and later at Monte Mario) deserves special mention (**6, 7, 9–16**). An image of the Sun about one metre in diameter is projected onto a screen, and the passage of each R.A. limb is timed across seven wires by four observers using the eye-and-ear method. The technique of obtaining four observations at each transit, introduced by Respighi in 1876, has two advantages: it decreases the probable error of a yearly mean because of the increased number of observations, and it enables differences of personal equation between observers to be calculated easily. On the other hand, the eye-and-ear observations across fixed wires would be expected to be inferior in accuracy to observations obtained with a self-recording moving-wire micrometer, and to involve greater personality differences.

This series of observations seems to provide strong evidence for an oscillation with a period of 22 years and an amplitude of a few tenths of a second of arc in the horizontal diameter. It has been claimed (**17**) that the Greenwich observations support this conclusion, providing evidence of an oscillation of about the same period and phase. A comparison of the two sets of observations, given below, offers no support to this claim.

The Greenwich results for the period 1851 to 1939 obtained with the Airy Transit Circle are given in Table I. The table exhibits the mean horizontal and vertical semi-diameters obtained from all the O–C diameter residuals published in the annual volumes of Greenwich Observations. It must be emphasized that corrections for personality have not been applied. Some of the data have been published previously (**18, 19**), some are taken from computations undertaken by R. T. Cullen for an unpublished investigation. The results have been tabulated in the form of semi-diameters to facilitate comparison with the Italian results.

TABLE I

Yearly mean horizontal and vertical radii of the Sun observed at Greenwich

Year	Horizontal semi-diameter	Number of observations	Vertical semi-diameter	Number of observations
	"		"	
1851·5	961·46	87	961·26	106
1852·5	1·74	103	1·60	112
1853·5	1·82	78	1·53	86
1854·5	1·19	109	1·18	111
1855·5	1·33	84	1·50	93
1856·5	1·12	104	1·24	109
1857·5	1·33	113	1·32	123
1858·5	1·33	126	1·36	132
1859·5	1·26	109	1·32	125
1860·5	1·19	72	1·00	72
1861·5	1·12	108	1·34	113
1862·5	0·91	81	1·26	87
1863·5	0·98	103	1·18	107
1864·5	1·26	105	1·28	111
1865·5	1·33	104	1·31	117
1866·5	1·26	95	1·26	103
1867·5	1·05	73	1·12	83
1868·5	1·26	111	1·16	126
1869·5	0·98	79	1·02	93
1870·5	0·98	106	1·18	119
1871·5	1·05	103	1·50	104
1872·5	0·98	107	1·50	109
1873·5	1·05	102	1·58	108
1874·5	1·12	94	1·74	95
1875·5	1·05	96	1·52	104
1876·5	1·05	99	1·30	96
1877·5	1·12	75	1·31	75
1878·5	1·12	77	1·15	72
1879·5	1·19	61	1·16	64
1880·5	1·26	99	1·13	104
1881·5	1·19	107	1·36	108
1882·5	1·26	87	1·48	97
1883·5	1·47	113	1·38	122
1884·5	1·32	100	1·44	100
1885·5	1·42	110	1·46	123

TABLE I—*cont.*

Year	Horizontal semi-diameter	Number of observations	Vertical semi-diameter	Number of observations
	″		″	
1886·5	961·46	115	961·43	121
1887·5	1·38	125	1·30	132
1888·5	1·33	84	1·26	96
1889·5	1·23	109	1·03	118
1890·5	1·28	124	1·23	141
1891·5	1·20	120	1·18	130
1892·5	1·02	136	1·11	139
1893·5	1·30	167	1·44	172
1894·5	1·09	149	1·23	158
1895·5	1·19	177	1·24	188
1896·5	1·02	147	1·20	147
1897·5	1·16	160	1·29	170
1898·5	0·99	143	1·12	150
1899·5	1·13	162	1·20	179
1900·5	1·07	145	1·10	154
1901·5	1·06	159	1·27	173
1902·5	0·92	119	1·08	145
1903·5	0·78	138	0·77	158
1904·5	0·96	139	0·98	150
1905·5	0·93	118	0·98	129
1906·5	0·90	113	0·97	117
1907·5	0·88	138	0·92	139
1908·5	1·11	130	1·16	139
1909·5	1·14	128	1·28	137
1910·5	1·02	122	1·12	136
1911·5	1·08	154	1·43	167
1912·5	0·84	131	1·22	144
1913·5	1·06	137	1·34	147
1914·5	1·10	148	1·40	163
1915·5	1·10	103	1·39	127
1916·5	0·95	111	1·07	125
1917·5	0·90	137	1·04	163
1918·5	0·98	124	0·90	137
1919·5	0·92	116	1·14	129
1920·5	0·98	127	1·04	140
1921·5	1·02	150	1·19	159
1922·5	0·96	114	1·16	118
1923·5	0·82	114	1·06	125
1924·5	0·72	112	1·16	122
1925·5	0·65	99	0·84	112
1926·5	0·79	131	0·91	140
1927·5	0·46	130	0·92	139
1928·5	0·64	135	0·92	149
1929·5	0·84	146	1·10	151
1930·5	0·66	115	0·84	131
1931·5	0·56	118	0·94	123
1932·5	0·72	116	1·04	126
1933·5	0·82	147	0·98	157
1934·5	0·74	133	1·04	146
1935·5	0·68	110	1·06	118
1936·5	0·46	107	1·06	114
1937·5	0·48	94	0·98	102
1938·5	0·56	121	1·24	131
1939·5	0·54	75	1·12	97

The values given in Table I do not agree exactly with those given by Miss Giannuzzi (**17**). The means in Table I were obtained by giving each observation unit weight, whereas Miss Giannuzzi first formed monthly means and then gave these equal weight in forming the annual means. The differences between the two sets of values obtained by these two different procedures are small in general. The Italian results for the horizontal semi-diameter are given in Table XI of the paper by Gialanella (**7**).

The two series of observations are compared in Fig. 1. The upper graph shows the two series of measurements of horizontal semi-diameters and the lower graph shows the Greenwich measurements in the vertical co-ordinate; measurements of the vertical diameter were not made at Campidoglio. The diagram also shows the dates of sunspot maxima and minima for the purposes of comparison.

An examination of the upper graph fails to show any obvious agreement between the variations found at the two observatories. Miss Giannuzzi, however, claimed that the Greenwich observations of horizontal diameter contained an oscillation with a period of between 22 and 24 years, agreeing in period and phase with an oscillation found from the Italian results. The conclusions she reached from her study of the Greenwich observations were as follows:

(i) There appears to be a secular drift in the Greenwich semi-diameters from about 1890 onwards, the semi-diameter decreasing at the rate of about $0''{\cdot}01$ per year; the drift is removed before the results are analysed.

(ii) A periodic analysis by a special method suggested the existence of two oscillations, one with a period between 22 and 24 years (mentioned above), and the other with a period between 6 and 8 years. Periods of about 22 years and 8 years have already been detected in the Campidoglio results; it is suggested by Miss Giannuzzi that the 22-year period represents a real oscillation of the horizontal diameter, since there is agreement in the phase as well as in period, whereas the 8-year period may be of atmospheric origin, since there is no agreement in phase.

(iii) Although the 22-year oscillations agree approximately in period and phase, there is a discrepancy in amplitude, the Greenwich oscillation having an amplitude between $0''{\cdot}1$ and $0''{\cdot}2$ and the oscillation found from the Italian results having an amplitude between $0''{\cdot}2$ and $0''{\cdot}5$.

In view of Miss Giannuzzi's results, the following tests were applied to the results plotted in Fig. 1:

(i) *Correlation.*—The correlation coefficient between the horizontal semi-diameters for the years 1876 to 1936 and the Italian results for the same period is $-0{\cdot}26$, or $-0{\cdot}07$ after removal of the secular drift from the Greenwich observations.

(ii) *Analysis for period.*—Inconclusive results were obtained from a normal periodogram analysis. The horizontal semi-diameters showed a suggestion of a seven-year period, and the vertical semi-diameters showed a suggestion of a ten-year period, but the evidence was not convincing in either case.

(iii) *Amplitude of variations.*—It is clear from a cursory inspection of Fig. 1 that the variations in the Greenwich semi-diameters are considerably smaller than those in the Campidoglio results. The standard deviation of the Campidoglio measures from their mean is nearly three times the standard deviation of the Greenwich measures from the Greenwich mean. This result is in reasonable

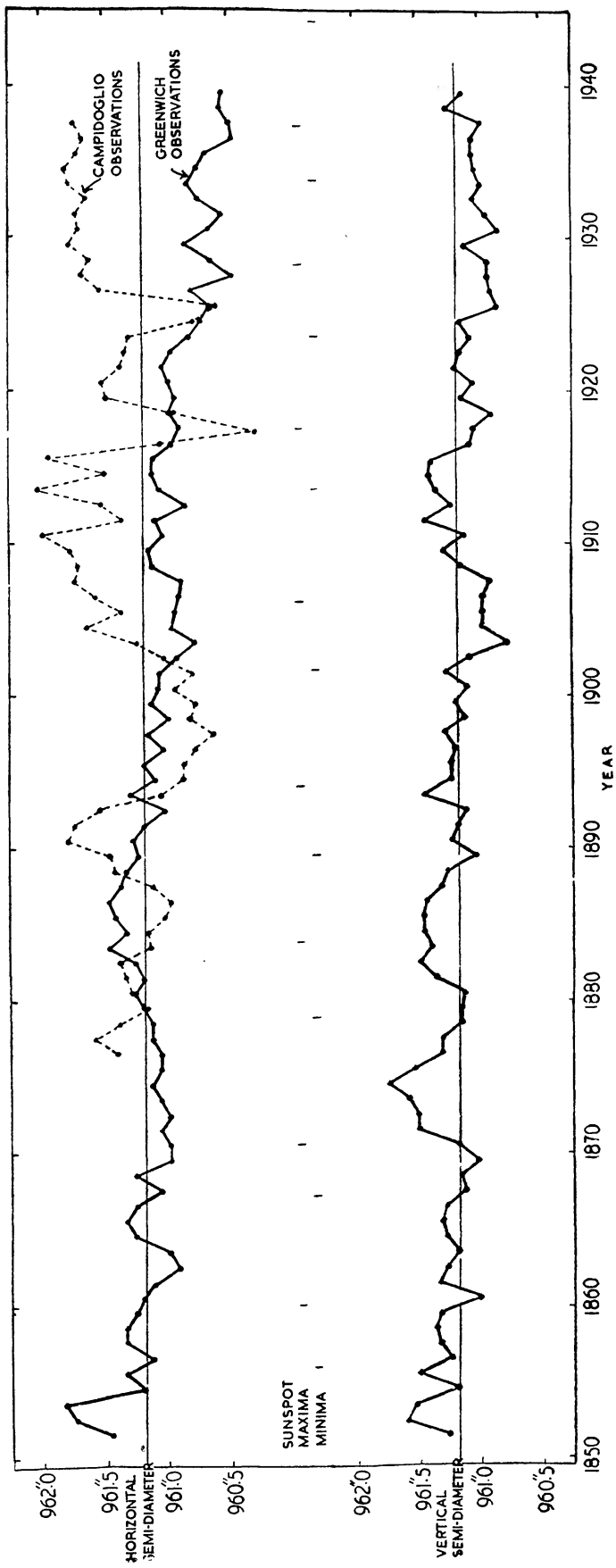

FIG. 1.—*Greenwich observations, uncorrected for irradiation and personality differences, of the horizontal and vertical semi-diameters of the Sun. The Campidoglio results for the horizontal semi-diameter are also shown.*

agreement with Miss Giannuzzi's conclusion given as (iii) above, but it is important evidence *against* the hypothesis that the variations represent real changes in the Sun's size, which would be expected to affect both series of measurements equally.

In the above discussion of the Greenwich observations, no account has been taken of the differing personal equations of observers and the differing distributions of the dates of observations from year to year; apparent changes in the annual means might arise from either of these two causes. The personal equations are systematic differences between observations of diameter made by different observers. Clearly, if an observer with a personal equation which is large compared with the mean of other observers' personalities obtains a large number of observations in one year and a small number in the next year, the mean semi-diameter will show a consequent change which does not represent a real change in the size of the Sun. Similarly, the annual term in the measurements made by each observer, i.e. the "irradiation" term found by Cullen (**20**), can give rise to apparent changes in mean diameter if the distribution of observations changes appreciably from year to year.

2. *The Greenwich observations from 1915 to 1937.*—In view of the importance of personality corrections and of the irradiation term, it was decided to attempt an analysis in which allowance could be made for their effects. Apart from these difficulties, the transit circle appears to be particularly suitable for the measurement of the horizontal diameter since the quantity measured, effectively the time interval between the passage of the two vertical limbs past a fixed point, is not affected by instrumental changes. The measured vertical diameters, however, could be affected to a small extent by changes in the scale values of the ZD micrometer and of the microscope micrometers used in obtaining the circle readings.

The observations obtained by five regular observers with exceptionally long periods of service between the years 1915 and 1936 provided the most suitable data. The introduction of the impersonal R.A. micrometer in 1915 forms a suitable starting point, since the personality of each observer in measuring the R.A. limbs probably changed with the new method of observing; it is possible that the personalities for measurements in the vertical direction also changed because of the consequent changes in observing technique. The total number of observations obtained by the five observers showed a sharp drop after 1936, owing to retirements from observing duties or to transfers to other instruments. There is therefore a poor "connection" with the new observers who replaced them. The names of the observers, the initials by which their observations are identified, and their periods of service as regular transit-circle observers are as follows:

Mr Witchell (W),	1902–1934,
Mr Cullen (RC),	1903–1935,
Mr Acton (HA),	1912–1937,
Mr Barton (HB),	1921–1937,
Mr Symms (LS),	1922–1937.

It was decided to collect the observations of both the horizontal and vertical diameters in order to compare the variations in the two co-ordinates.

The published observations of solar diameter are in the form of residuals, either (C–O) or (O–C), between the observed diameter O, and the computed

diameter C published in the Nautical Almanac for the time of transit. The first step was to correct each residual for the irradiation term found by Cullen (**20**). This is an annual term in the measured diameters, both horizontal and vertical, varying approximately with the secant of the Sun's zenith distance; the Sun is observed large in summer and small in winter.

After corrections for irradiation had been applied, yearly means were formed for each observer. These means will be referred to as "individual means". The yearly means were then examined for personality differences by the method described below. The appropriate personality corrections required to refer all observations to a standard observer were then applied, and a mean formed for each year, by combining with appropriate weights the corrected individual means; this mean will be referred to as the "combined mean" for that year. The results are tabulated and discussed in a later section.

3. *The irradiation correction.*—Throughout this section results given refer to diameters, *not* semi-diameters; this is to facilitate comparison with Cullen's results. The correction applied for irradiation was $-0''{\cdot}55+0''{\cdot}30\sec z$, where z is the Sun's zenith distance. The correction was not computed for each observation; instead, a mean value of z for each month was used, and the same correction applied to each observation in that month, according to Table II.

TABLE II

Irradiation corrections

Month	Correction to be added to (O–C)	Month	Correction to be added to (O–C)
	″		″
Jan.	+0·45	July	−0·20
Feb.	+0·15	Aug.	−0·17
Mar.	−0·05	Sept.	−0·10
Apr.	−0·15	Oct.	+0·06
May	−0·19	Nov.	+0·31
June	−0·21	Dec.	+0·57

These values are taken from Cullen's paper. They were obtained from an analysis of the observations made by seven regular observers in the period 1915–1925. Some of the observations used are, of course, contained in the present investigation. The constant term, $+0''{\cdot}55$, was chosen so that the mean of all the observations considered was not altered by the application of the irradiation corrections.

The present work provided a good opportunity of confirming the values obtained by Cullen. The corrections given in Table II were first applied and corrections for personality obtained, in a manner to be described. The personality corrections were then applied, and all the observations were classified according to month. A least-squares solution, to fit the new diameter residuals for each month (horizontal and vertical combined) to a curve of the form $a+b\sec z$, showed that an additional correction of $+0''{\cdot}21\ +0''{\cdot}05\sec z$ was required. The constant term is of no importance; it arises mainly because the personality corrections in the present investigation have been referred to observer W as standard, whereas Cullen used the mean (O − C) of his seven observers as the standard. The coefficient of the second term indicates that the coefficient of

$\sec z$ in the complete correction should be $+0''\cdot35$. The probable error of this coefficient, however, is about $\pm0''\cdot06$ and it was therefore not considered worthwhile to apply additional corrections for irradiation, the effect of which would in any case be small in the present investigation.

Miss Giannuzzi, in a recent paper (**21**), has also investigated the irradiation term in the Greenwich observations. She collected all the observations made between 1851 and 1937 and arranged them according to month. The monthly means have not been analysed for a $\sec z$ term in her paper, but this can be done very easily and yields a coefficient of $+0''\cdot33$, a value intermediate between the two quoted above.

No significant differences in the irradiation terms of different observers could be detected; nor was there any noticeable difference between the horizontal and vertical diameters in this respect. It must be emphasized, however, that the data are not really sufficient for detailed consideration of these points.

After removal of the irradiation term, the probable error of a single observation is about $\pm0''\cdot87$ for a horizontal diameter and $\pm0''\cdot63$ for a vertical diameter. As is to be expected, these probable errors are smaller than the value (about $\pm1''$) for both diameters before correcting for irradiation.

4. *Personality corrections.*—The difference between the individual mean semi-diameters obtained by two observers in the same year was assumed to be due to personality differences and a weighted mean of the differences for each pair of observers was formed. Comparison of the weighted mean with the individual differences showed that the first one or two differences obtained with each new observer tended to show rather a large scatter, presumably due to inexperience. It was therefore decided to revise the personality solution by omitting the first two years' observations of each new observer and the first two years' observations of every observer after the introduction of the impersonal micrometer, i.e. no observations made prior to 1917 were kept.

TABLE III

Personality corrections to semi-diameters

Observer	Horizontal personality	Vertical personality
	″	″
W	0·00	0·00
RC	−0·24	+0·04
HA	−0·02	+0·25
HB	+0·11	+0·41
LS	+0·34	+0·16

The personality corrections given by the weighted means are not self-consistent, because of the effects of weighting. For example, the (horizontal) values $W-RC=+0''\cdot24$ and $W-HB=-0''\cdot03$ would suggest $RC-HB=-0''\cdot27$, whereas the actual value is $-0''\cdot38$. A compromise solution was therefore obtained by the method of least-squares. The results are shown in Table III, which gives the correction required to refer an observed horizontal or vertical semi-diameter to W as standard.

The personality corrections obtained by this procedure are independent of any changes in the Sun's diameter from year to year. It is, however, questionable

TABLE IV

Horizontal semi-diameters corrected for personality

Year	W	RC	HA	HB	LS	Combined mean
	"	"	"	"	"	"
1917·5	960·90	960·22	960·82	...	...	960·84
1918·5	1·08	...	0·72	...	...	0·94
1919·5	0·78	0·58	0·88	...	...	0·76
1920·5	0·92	0·40	0·64	...	...	0·66
1921·5	0·91	0·73	0·65	...	...	0·75
1922·5	0·64	0·96	0·58	..	...	0·74
1923·5	0·60	0·54	0·66	960·74	...	0·63
1924·5	1·07	0·72	0·96	0·78	960·72	0·84
1925·5	0·58	0·86	0·82	0·79	0·50	0·74
1926·5	0·48	0·82	1·04	0·68	1·21	0·88
1927·5	0·96	0·75	0·70	0·55	0·95	0·76
1928·5	0·74	0·94	0·59	1·08	0·60	0·80
1929·5	1·00	1·23	0·92	1·20	0·54	1·02
1930·5	0·76	1·04	1·19	0·96	0·48	0·91
1931·5	0·71	0·86	0·87	0·74	1·37	0·91
1932·5	0·91	0·81	0·89	1·09	1·22	0·97
1933·5	0·94	1·06	0·92	1·02	1·04	1·00
1934·5	0·82	1·05	1·06	0·80	0·96	0·96
1935·5	...	0·76	1·00	0·78	1·16	0·90
1936·5	...	1·00	0·70	0·90	0·88	0·86

TABLE V

Vertical semi-diameters corrected for personality

Year	W	RC	HA	HB	LS	Combined mean
	"	"	"	"	"	"
1917·5	960·86	960·59	960·75	...	...	960·82
1918·5	1·04	...	0·88	...	...	0·97
1919·5	1·06	1·08	0·96	...	...	1·02
1920·5	0·98	1·00	0·94	...	...	0·98
1921·5	1·29	0·93	0·95	...	...	1·04
1922·5	1·10	0·96	1·23	...	...	1·11
1923·5	1·26	0·79	1·04	961·04	...	1·04
1924·5	1·18	1·12	1·10	1·37	961·26	1·20
1925·5	0·86	0·95	0·96	1·14	0·82	0·96
1926·5	1·24	1·26	1·01	0·82	1·34	1·10
1927·5	1·11	1·24	1·12	0·92	1·38	1·16
1928·5	1·28	1·16	1·26	1·30	1·32	1·26
1929·5	1·32	1·70	1·52	1·50	0·55	1·39
1930·5	1·30	1·28	1·30	1·20	0·81	1·17
1931·5	1·16	1·28	1·27	1·32	1·48	1·29
1932·5	1·20	1·34	1·30	1·56	1·36	1·36
1933·5	0·98	1·25	1·46	1·30	1·45	1·30
1934·5	1·24	1·45	1·44	1·28	1·56	1·40
1935·5	...	1·33	1·38	1·26	1·60	1·38
1936·5	...	1·89	1·35	1·66	1·58	1·59

whether personality differences remain strictly constant from year to year, and whether the mean personality of all observers is constant. If the personalities of all observers are subject to changes of the same sign the combined means will obviously be affected. The apparent variations in the solar diameters therefore include the effects of possible real variations and changes in mean personality.

The results obtained by each observer, corrected for personality, for the horizontal and vertical semi-diameters are tabulated in Tables IV and V. The combined mean for each year has also been tabulated for the two co-ordinates. It must be emphasized that only constant corrections have been applied for personality; no attempt has been made to remove slopes or " waves " in differences between two observers. Changes in personality peculiar to one observer show up as a systematic drift of his results from the mean. For example, the measurements of horizontal semi-diameter obtained by RC show a tendency to increase over the entire period covered by his observations.

An indication of the magnitude of changes of personality to be expected can be obtained by dividing the data in these tables into groups. For example, we can compare the mean personality differences of the observers W, RC and HA for the years 1919·5 to 1926·5 with those for the years 1927·5 to 1934·5. The results are given in Table VI. It will be seen that there are long-term changes of two or three tenths of a second in personality differences, and the possibility of comparable changes in combined mean semi-diameters, due to personality changes, cannot be excluded.

TABLE VI

Personality differences in two periods of eight years

	Horizontal semi-diameters		Vertical semi-diameters	
	W–RC	W–HA	W–RC	W–HA
	″	″	″	″
1919·5 to 1926·5	−0·19	−0·05	+0·15	+0·35
1927·5 to 1934·5	−0·35	+0·01	−0·10	+0·12

5. *Discussion of results.*—The mean values for the horizontal and vertical semi-diameters have been meaned in pairs to give points corresponding to the beginning of each year. These points are plotted on a larger scale in Figs. 2 and 3; Fig. 4 is a plot of mean sunspot areas for comparison.

The variations in these values are rather greater than can be accounted for as random scatter of the observations; however, it will be shown that they could be explained as variations in personality and do not necessarily represent real variations in the size of the Sun.

Working from the probable errors of $\pm 0''\cdot 87$ for a horizontal diameter and $\pm 0''\cdot 63$ for a vertical diameter obtained above, and ignoring possible variations in personality, we should expect the probable error of one of the plotted points to be $\pm 0''\cdot 05$ at most. The total ranges in semi-diameter are rather larger. The greatest difference in the horizontal semi-diameters is between the years 1923·0 and 1933·0, the values and probable errors being as follows:

$$1923\cdot 0: \quad 960''\cdot 68 \pm 0''\cdot 05$$
$$1933\cdot 0: \quad 960''\cdot 98 \pm 0''\cdot 03.$$

Thus the range is nearly four times the sum of the probable errors. For the vertical semi-diameters the extreme values are:

$$1918\cdot 0: \quad 960''\cdot 89 \pm 0''\cdot 02$$
$$1936\cdot 0: \quad 961''\cdot 48 \pm 0''\cdot 04$$

and the range is nearly ten times the sum of the probable errors.

It must be emphasized that the probable errors quoted have been deduced from the internal accordance of each observer's measures in any one year; they do not, therefore, include the effects of possible random and systematic errors in the personality corrections applied. The effect of uncertainties in the personality corrections can be studied by considering the internal agreement of the diameters obtained by *different* observers in the same year. For example, working from the scatter of the individual means for each year, we can estimate the standard deviation from a constant value (nearly enough the mean of all observations) to be expected in the yearly means for all observers combined, on

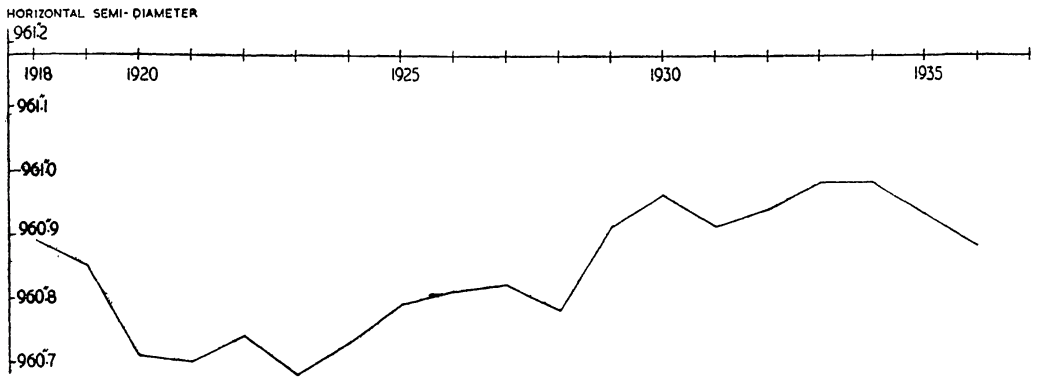

FIG. 2.—*Mean corrected horizontal semi-diameters.*

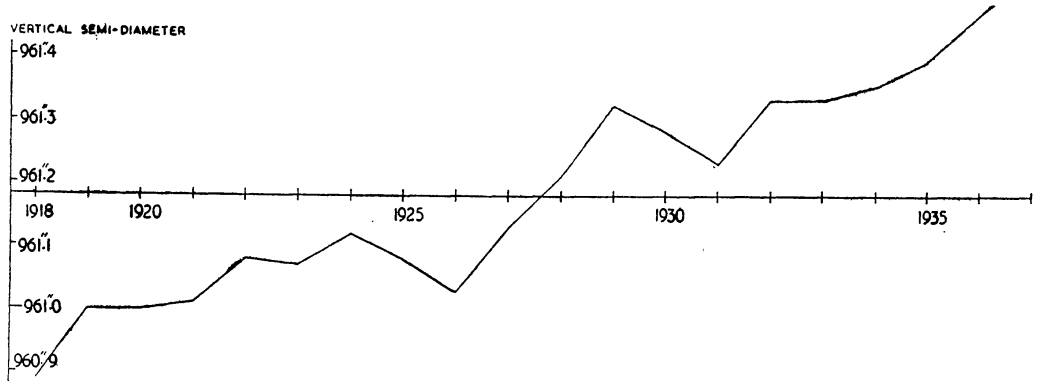

FIG. 3.—*Mean corrected vertical semi-diameters.*

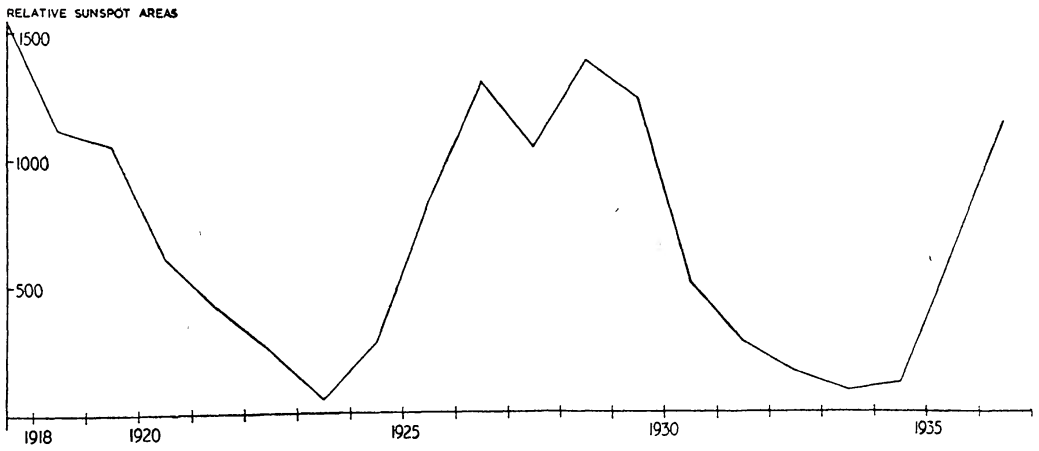

FIG. 4.—*Relative sunspot areas.*

the assumption that there are no real variations in the diameter of the Sun. The problem of weighting is awkward, since the probable error of an observer's mean for a year is only partly dependent on the number of observations obtained by him; any systematic error due to a departure of his personality correction for that year from its mean value over several years will not depend on the number of observations. Since the systematic errors seemed likely to be of more importance than the random errors, it was decided to give equal weight to each annual mean, independent of the number of observations.

The standard deviations calculated in this way from the discordances between annual means for individual observers were:

0″·26 for the horizontal semi-diameters

0″·20 for the vertical semi-diameters.

The actual standard deviations from a constant value of the combined annual means are:

0″·22 for the horizontal semi-diameters

0″·38 for the vertical semi-diameters.

These values show that, if anything, the combined yearly means for the horizontal semi-diameters are more nearly constant than would be expected. This conclusion is the opposite of Miss Giannuzzi's; she used the observations obtained by a larger number of observers without applying personality corrections, on the assumption that changes in the mean personality corrections would then be sufficiently small to be ignored. The present analysis suggests that this assumption may not be justified. It can be seen from Table IV that the scatter of the individual means, corrected for personality, about the combined mean is too large to inspire any confidence in the reality of the variations from year to year.

With the vertical semi-diameters the position seems to be quite different; the means seem to show larger variations than would be expected. The main contribution to the comparatively large calculated standard deviation comes from the progressive change in the means. An inspection of either Table V or Fig. 3 shows fairly clear evidence of a positive slope in the yearly means. This slope appears to be confirmed by most, if not all, observers. The slope is equivalent to an increase of about 0″·03 per year in the semi-diameter, i.e. about three times that found by Miss Giannuzzi in the horizontal semi-diameters, and of the opposite sense. There is no evidence to indicate whether the drift should be interpreted as a real change in the diameter of the Sun, as an instrumental or atmospheric effect, or as a drift in the mean personality.

There does not appear to be any marked drift in the uncorrected vertical semi-diameters meaned for all observers. Indeed, the uncorrected results tabulated in Table I for both co-ordinates behave rather differently in the period 1917 to 1937 from those in Tables IV and V for the same period. The uncorrected horizontal semi-diameters for the dates corresponding to the extremes of the corrected horizontal semi-diameters are:

1923·0: 960″·89

1933·0: 960″·77.

The change is of opposite sign to that in the corrected results. For the uncorrected vertical semi-diameters the results are:

1918·0: 960″·97

1936·0: 961″·06.

The change is of the same sign as that in the corrected results, but is much smaller.

The differing shapes of the uncorrected and corrected curves demonstrate the importance of personality corrections. It seems probable that at least some of the difference can be explained by the fact that two new observers with large personalities of the same sign in both co-ordinates started observing in 1923 and 1925 respectively. Their observations have an increasing effect on the uncorrected means from these dates onward.

An inspection of Figs. 2, 3 and 4 shows that there is no obvious connection between sunspot activity and the apparent variations in diameter. There is, in fact, no significant correlation between the two phenomena.

It must be concluded that the Greenwich observations considered here do not provide any clear evidence of the existence of real variation in the size of the Sun.

Royal Greenwich Observatory,
Herstmonceux Castle, Sussex :
1955 *June* 16.

References

(1) A. Auwers, *Astr. Nach.*, 3068, 367, 1891.
(2) L. Ambronn, *Gott. Abhand.*, N.F. **3,** No. 3, 1905.
(3) C. L. Poor, *Ap. J.*, **22,** 305, 1905.
(4) L. Ambronn, *Ap. J.*, **23,** 343, 1906.
(5) A. Secchi, *C.R. Acad. Sci. Paris*, **75,** 606 and 1581, 1872; *Ibid.*, **77,** 253 and 905, 1873.
(6) L. Gialanella, *Contr. Sci. Oss. Roma*, Nos. 107, 112, 1943.
(7) L. Gialanella, *Contr. Sci. Oss. Roma*, No. 109, 1943.
(8) C. L. Poor, *Ap. J.*, **22,** 103, 1905.
(9) M. Cimino, *Contr. Sci. Oss. Roma*, No. 122, 1945.
(10) M. Cimino, *Contr. Sci. Oss. Roma*, No. 128, 1946.
(11) T. Fortini, *Contr. Sci. Oss. Roma*, No. 150, 1949.
(12) T. Fortini, *Contr. Sci. Oss. Roma*, No. 153, 1949.
(13) L. Gialanella, *Contr. Sci. Oss. Roma*, No. 167, 1951.
(14) L. Gialanella, *Contr. Sci. Oss. Roma*, No. 171, 1952.
(15) M. Cimino, *Contr. Sci. Oss. Roma*, No. 193, 1953.
(16) M. Cimino, *Contr. Sci. Oss. Roma*, No. 196, 1953.
(17) M. A. Giannuzzi, *Mem. Soc. Astron. Ital.*, **XXIV,** No. 3, 1953.
(18) G. B. Airy, *M.N.*, **22,** 80, 1862.
(19) W. G. Thackeray, *M.N.*, **45,** 389, 1885.
(20) R. T. Cullen, *M.N.*, **86,** 344, 1926.
(21) M. A. Giannuzzi, *Rend. Sc. Lincei*, **XVIII,** 62, 1955.