THE HORIZONTAL AND VERTICAL SEMI-DIAMETERS OF THE SUN OBSERVED AT THE CAPE OF GOOD HOPE (1834-1887) AND PARIS (1837-1906): A REPORT ON WORK IN PROGRESS*

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ABSTRACT

Cape and Paris meridian observations of the solar limbs which permit an estimate to be made of the solar semi-diameter are being surveyed, sampled, and compared with Greenwich and U.S. Naval Observatory observations. Significant systematic errors have been found in the Paris work and have been correlated with changes of instruments and observers. It is unlikely that further work on the Paris series would shed light on the problem of changes in the solar semi-diameter. Preliminary results from the more stable Cape series indicate that work should continue on the compilation of data from Cape observations of the sun.

INTRODUCTION

The possibility of a secular decrease in the apparent solar semi-diameter (referred to standard conditions) has been suggested from studies of meridian circle observations made at the Royal Greenwich and the U.S. Naval Observatories (refs. 1,2,3). Two other series of observations not previously discussed are available from the Royal Observatory at the Cape of Good Hope (Cape) in South Africa from 1834 to 1887 (ref. 4) and at the Paris Observatory (Paris) from 1837 to 1906 (ref. 5). The Cape series is of particular interest because of the Cape's southern hemisphere location. The Paris series is of interest because of the 70 year time-span.

A method for reducing raw observations to standard conditions is given, the method was applied to selected subsets of the original mass of observational material, and the results are discussed.

DATA ANALYSIS

Solar observations were reduced as follows (ref. 6):

$$SD_H = \frac{15R\Delta\alpha\cos\delta}{2S}, \qquad (1)$$

where SD_H = horizontal semi-diameter at unit distance (one A.U.),
R = earth-sun distance in units of A.U. at the time of observation,

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$\Delta\alpha$ = measured difference in time between the east and west limbs,

S = a correction factor for the sun's motion in right ascension during the time between meridian passage of the east and west limbs. $S = 1/(1-\Delta a^s/3609.86)$, where Δa^s is the rate of change in right ascension of the sun in units of seconds of time per mean solar hour. (See table I for the monthly value used in any year.), and

δ = sun's apparent observed declination.

In some cases the north polar distance (NPD) was given, rather than the declination. In those cases, sin(NPD) was substituted for $\cos\delta$.

In the other coordinate:

$$SD_V = \frac{R\Delta\delta}{2}, \qquad (2)$$

where SD_V = vertical semi-diameter at unit distance (one A.U.), and

$\Delta\delta$ = measured difference between north and south limb declinations corrected for refraction.

Our strategy was to survey several years at the beginning and end of an instrumental series. Annual averages of SD_H and SD_V have been computed for Cape for the years 1834, 1884-1887, and 1861-1865 and are summarized in table II. Annual averages of SD_H and SD_V from Paris for the years 1837-1841, 1859-1867, and 1885-1890 are summarized in table III.

The entire Cape series was observed with no significant change in instrumentation or observers. However, the Paris series is composed of subsets of observations with four diffent instruments as indicated in table III. Significant changes in the observing staff from one year to the next were also noted.

PRELIMINARY RESULTS

CAPE

A test of the Cape results SD_H and SD_V of table II for a linear rate with time, T, by means of a least squares fit yielded the solutions $d(SD_H)/dT = -0.6 \pm 0.6$ seconds of arc per century and $d(SD_V)/dT = -0.4 \pm 0.4$ seconds of arc per century from 1834 to 1887, and 1861 to 1887, resp. From a statistical point of view, these results can barely be regarded as significant. However, since the mean errors are of the same order of magnitude as the rates and not very much larger, and since the two independent solutions are in better agreement with each other than expected from their relative errors, there is some indication that a clearer picture may emerge if the survey of Cape sun observations is broadened to include data from the time interval 1865 to 1884, and close attention is paid to the change in the mix of observers from one year to the next.

This preliminary result may be compared with the results of (1) Eddy and Boornazian (refs. 2,3) who found a secular decrease of -2" per century in

SD_H and $-0''.8$ per century in SD_V from Greenwich and U.S. Naval Observatory meridian observations;(2) I. Shapiro (ref. 7) who from transits of Mercury found that any decrease in the solar diameter is likely to be under $0''.3$ per century;(3) D. Dunham, et al. (ref. 8) who found from an analysis of solar eclipses that the solar radius has contracted 0.34 ± 0.2 seconds of arc in 264 years; and(4) A. Wittman (ref. 9) who from the agreement between the mean of Tobias Mayer's observations of the sun, 1756-1760, and recent photoelectric results obtained in the 1970's finds no support for a secular decrease in the solar radius.

PARIS

The Paris results are inconclusive. Large systematic differences of the personal equation of individual observers having an effect as large as two seconds of arc on the determination of SD_H have been documented, and explain the discordant values of SD_H for 1866,1867, and 1902-1906. On the other hand, the significant decrease of SD_H from the 1840's to the 1860's is consonant within their relative errors with a similar decrease in the Greenwich results.

There is no significant change in the Paris SD_V of the 1837-1841 period compared with the 1859-1863 period, which is not in agreement with the Greenwich results over the same interval of time. Since different instruments were used at Paris in the 1837-1841 and 18 9-1863 periods, i.e., the Fortin Mural Circle was used in the first period and the Gambey Mural Circle was used in the second period, systematic instrumental effects probably are at the root of the disagreement between Paris and Greenwich over that interval of time.

It was very disturbing to find that for the subset of observations made with the Grande Instrument Meridienne from 1863 to 1906 for which we have values of SD_V, the values were systematically larger than the earlier Paris values by about 1.5 seconds of arc, and also systematically larger than the Greenwich SD_V by about the same amount in the interval 1863 to 1906. This abrupt change in the system was probably caused by an instrumental change rather than an observer change. We have been able to document that changes of observer from one year to the next which grossly affect the SD_H (compare SD_H values 1885-1889 to SD_H values 1902-1906) cause no significant change in the corresponding SD_V values observed with the same instrument.

FUTURE WORK

Our next efforts will focus on completing the discussion of the Cape observations and then turning to the long series of the U.S. Naval Observatory. We hope to use concurrent Naval Observatory observations of the limbs of Jupiter and Saturn to indicate how diameter measurements can be affected systematically by personal equation and changes in instrumentation apart from changes which may occur as the result of severe punishment of the instrumentation during solar observations.

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TABLE I. S, A CORRECTION FACTOR FOR THE MOTION OF THE SUN

Jan.	1.00297	July	1.00281
Feb.	1.00271	Aug.	1.00259
Mar.	1.00253	Sept.	1.00249
Apr.	1.00256	Oct.	1.00258
May	1.00274	Nov.	1.00284
June	1.00288	Dec.	1.00307

TABLE II. ANNUAL MEANS OF SOLAR SEMI-DIAMETERS FROM OBSERVATIONS AT CAPE

Year	SD_H	No. of Obsns.	SD_V	No. of Obsns.
1834	961".50	132	--	0
1861	961.25	61	962".35	37
1862	960.63	37	962.04	32
1863	961.19	42	962.43	33
1864	961.57	54	962.29	53
1865	961.50	68	962.13	65
1884	960.86	69	962.09	77
1885	961.16	19	962.17	19
1886	961.34	141	962.27	150
1887	961.09	175	962.09	179

TABLE III. ANNUAL MEANS OF SOLAR SEMI-DIAMETERS FROM OBSERVATIONS AT PARIS

Year	SD_H	No. of Obsns.	SD_V	No. of Obsns.
Lunette Meridienne de Gambey (LMG)			Fortin Mural Circle	
1837	962".24	146	960".56	20
1838	962.62	111	960.70	4
1839	962.26	121	--	0
1840	962.75	142	961.35	11
1841	962.03	93	960.92	17
	LMG (continued)		Gambey Mural Circle	
1859	961.90	136	--	0
1860	961.20	77	961.28	3
1861	961.55	108	960.49	4
1862	960.67	42	961.56	8
1863	960.57	58	961.25	36
Grande Instrument Meridienne (in both coordinates)				
1863	961.19	25	963.18	20
1864	961.54	102	962.45	141
1865	960.62	101	961.71	93
1866	962.68	54	962.67	45
1867	962.03	76	962.50	73
1885	961.20	114	962.39	96
1886	961.25	126	962.44	119
1887	961.68	92	962.56	90
1888	961.29	93	962.45	57
1889	961.48	173	962.54	79
1902	962.85	105	962.42	93
1903	962.87	93	962.29	92
1904	962.80	97	962.49	89
1905	962.92	88	962.52	82
1906	963.05	88	962.54	87