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Solar diameter observations at Observatório Nacional in 1997-1998

E.G. Jilinski[1,2], **S. Puliaev**[1,2], **J.L. Penna**[1], **A.H. Andrei**[1], **and F. Laclare**[3]

[1] Observatório Nacional/CNPq, Brasil
[2] Pulkovo Observatory, Russia
[3] CERGA/Observatoire de la Côte d'Azur, France

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Abstract. In January 1997, at the Observatório Nacional (ON), Rio de Janeiro, Brazil, CCD observations of the solar diameter with a Danjon astrolabe equipped with a variable angle reflecting prism began. This prism is operated manually and enables to observe the Sun many times per day and all year round on the Southern latitude $\varphi = -22°54'$.

Thanks to this and owing to a large number of sunny days at Rio de Janeiro, a high density of observations was achieved - 2900 East and 1730 West observations during the first 18 months.

Results of the observations are available in electronic form in the SIMBAD database and at the World Wide Web page of the Observatório Nacional, Solar Radius Data: http://obsn.on.br/radius/.

Key words: Sun: general; fundamental parameter

1. Introduction

A program for solar observations with a CCD astrolabe, aiming to monitoring variations of the apparent diameter, has been pursued since 1997, January, at the Observatório Nacional (ON), Rio de Janeiro ($\varphi = -22°54'$). The program is part of a collaboration with the Observatoire de la Côte d'Azur (CERGA), and the analysis of its first results was published elsewhere (Jilinski et al. 1998). The measurements follow the fundamental principle of astrolabe observations, relying on the coincidence of the direct and mirrored images as way to fix a given zenith distance. They are largely independent from reference definitions and from instrumental biases, provided the instrument stability is met between the transits of the upper and lower limbs of the Sun. The required stability is at daytime seeing level for the pointing and at one milli-second for time recording. Details of the method and description of the instrument were also produced by the french group (Irbah et al. 1994; Sinceac et al. 1998). Here the results of the campaign from 1997, January 10th to 1998, June 30th are presented.

Observations at the ON were made with a variable angle prism, between 27° and 58° of zenith distance. The operation without rotating shutter was preferred (Chollet 1996). The images are acquired by a COHU # 4710 CCD camera. The camera is IR sensitive ($4000 - 10000$ Å). The effective wavelength is 6400 Å. Observations are taken daily, East and West of the solar meridian transit. The use of the variable angle prism, combined with the latitude of astrolabe and usually uncloudy weather enabled to get the measurements all year round.

Send offprint requests to: E.G. Jilinski, Observatório Nacional/CNPq, R. Gal. José Cristino 77, CEP20921-400, Rio de Janeiro, Brasil. E-mail: jilinski@on.br

2. Results and discussion

The period of observations can be divided in two, before and after January 1st, 1998, when the filter after the image vehicle was swapped by one with a narrower bandpass. The error of a single observation of the solar semi-diameter, in the first part, is $0''.63$ for the East and $0''.64$ for West observations. In the second part the errors became smaller, and are $0''.57$ and $0''.61$, for the East and West observations correspondingly. With the new filter the width of the measured borders of the Sun became narrower and, as such, the definition of the limb of the Sun became more precise and the error of the diameter measurement decreased a little. Figure 1 brings the histograms of the observed semi-diameter values distribution in these two half-periods.

There is a difference between the observations quality from East and West transits. The average temperatures for East and West observations depend on the season and vary from +25°C in winter to +45°C, and sometimes even higher, in summertime. However, the air temperature in

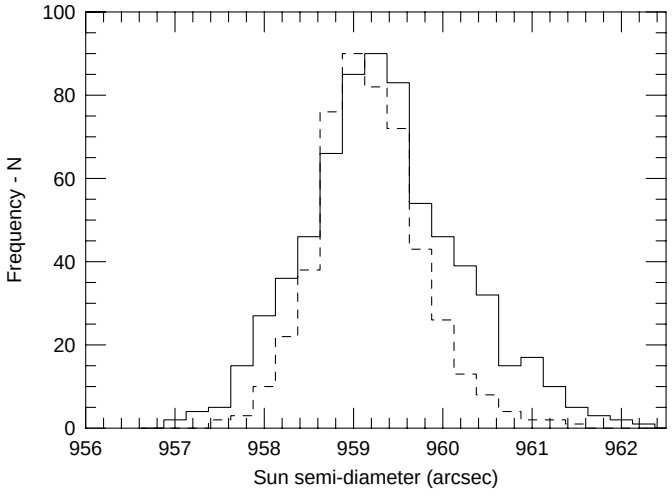

Fig. 1. Histogram of the observed semi-diameter distribution. Solid line refers to the observations made before January 1st, 1998 while the dashed line refers to those made later. The plot demonstrates clearly that the errors of observations became smaller after the narrower bandpass filter was installed

the morning is some 6 to 8°C lower than after midday, while the variation of the temperature in the morning (during East observations) is typically 4°C higher than after midday (West observations). The agitation of the images is much smaller in the afternoons than in the mornings. Even the visual inspection of the images on the monitor during the observations reveals the effect.

Fried's parameter r_0 (Irbah et al. 1994) is, thus, larger for West observations (4.2 cm), than for the East ones (3.8 cm). That is, the seeing conditions are better after midday, the atmosphere being more stable at that time. The understanding of the process delayed the start of West observations till April 1997.

Normally, about 20 or more, up to 30, observations, on each side of the Sun's meridian cross, are made in summer months. These figures fall to about 10 or less observations, on each side, in June when the Sun is comparatively low above the horizon. The summer months, December to February, are mostly rainy at Rio de Janeiro, so during these months we have usually less observational days than in winter (June to August) but much more diameter measurements. In total there were 246 days of observation till June 30th, 1998.

The error for a single observation is slightly larger than the one obtained at the Calern Observatory (0.″3) owing to the environmental conditions of the ON site. The average daily error of the mean observed value of the solar semi-diameter for the first half-period is 0.″21, both for the eastern and western observations. In the second half-period the daily error became smaller and is 0.″18 for the East and 0.″19 for the West observations.

Figure 2 gives the values of the solar semi-diameter reduced to the one astronomical unit plotted against the Modified Julian Day. Each point represents the value of the mean daily semi-diameter. East and West series are differently represented. The larger scatter of the initial observations is evident, although no systematic offset is apparent. On the contrary, the average values for the 1997 and 1998 summer observations agree well.

In the Table 1, number of the days of observation, total number of observations during a month and monthly averages are presented, both splitting East and West observations and combining them together. An analysis on the average values was already presented (Jilinski et al. 1998) and a forthcoming paper discussing the jointly results obtained in Calern and at ON is in preparation.

The complete results of the daily series can be retrieved in electronic form from the SIMBAD database and from the homepage of the Observatório Nacional (http://obsn.on.br/radius/). For the electronic form, the complete daily series are given: the number of observations, the semi-diameter mean value, its rms error, the date, the Modified Julian Date and the error for a single observation. The data are given for eastern and western observations separately.

In spite of the hard weather conditions of the observations, the instrument performed rather stably. No dependence was found for the observed semi-diameter on zenith distance, time length of observations (that vary from 2 to 7 min), azimuth or heliographic latitude of CCD scan across the Sun disc.

3. Conclusions

Observations of the solar diameter during 18 month from January 1997 to June 1998, to a total of 4630 single measurements were made at the ON. The error of a single observation is around 0.″6. Excepted some difference in the quality between the eastern and western measurements, no systematic effect is found, either from instrumental, weather or observational nature. In particular, the stability of the variable angle prism was confirmed. The daily measurements can therefore be grouped, resulting in 246 daily averages, to a precision better than 0.″2.

Further observations are highly desirable to improve the equipment performance and to study the solar semi-diameter variations in time. These are duly being conducted and currently a stepping up is planned for the dome of observation and for the instrument itself, along the lines of DORaySol (Delmas 1997).

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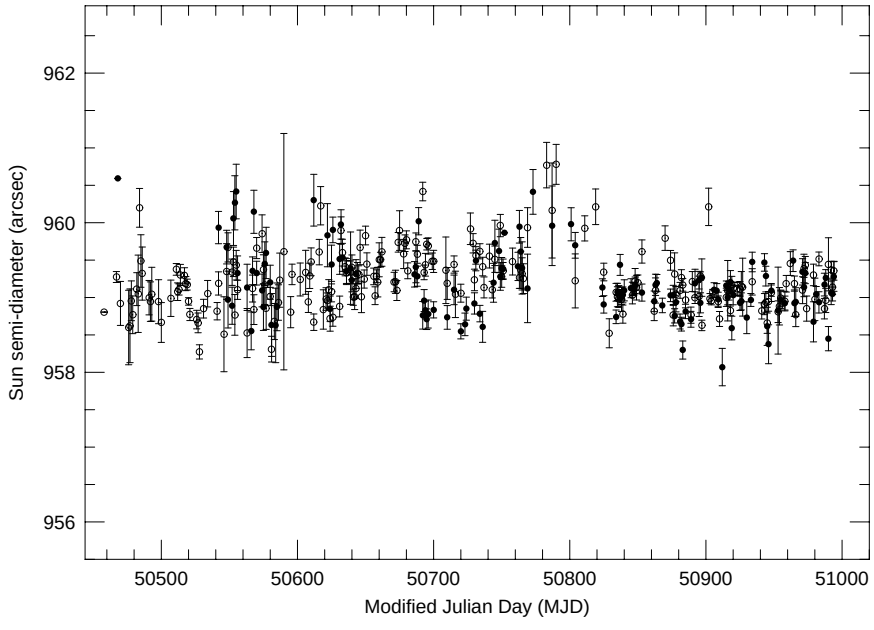

Fig. 2. Values of the Sun semi-diameter vs. Modified Julian Day observed at the ON. East observation - open circles and West ones are black circles. Each point represents a mean daily value of the Sun semi-diameter with its average error i.e. average error bar of $\pm 0''.20$

Table 1. Monthly average semi-diameters obtained at ON (in arcsec) from January 1997 to June 1998. The "days" column displays the number of observational days during the month, while the "num.obs." column brings the total number of observations during the month

Month	days	num. obs.	East transits	days	num. obs.	West transits	days	num. obs.	All transits
January 1997	7	44	958.85 ± 0.09				7	44	958.85 ± 0.09
February	11	120	959.16 ± 0.12				11	120	959.16 ± 0.12
March	14	217	958.98 ± 0.08				14	217	958.98 ± 0.08
April	13	156	959.09 ± 0.10	12	131	959.56 ± 0.18	25	287	959.31 ± 0.11
May	13	114	959.14 ± 0.12	9	83	959.08 ± 0.12	22	197	959.11 ± 0.08
June	15	142	959.15 ± 0.11	5	40	959.67 ± 0.25	20	182	959.28 ± 0.11
July	22	288	959.32 ± 0.06	7	54	959.47 ± 0.09	29	342	959.36 ± 0.05
August	13	216	959.54 ± 0.07	4	57	959.51 ± 0.17	17	273	959.53 ± 0.06
September	12	189	959.47 ± 0.11	9	147	958.81 ± 0.05	21	336	959.19 ± 0.10
October	13	251	959.49 ± 0.08	13	181	959.21 ± 0.12	26	432	959.35 ± 0.07
November	6	94	959.44 ± 0.11	6	105	959.65 ± 0.19	12	199	959.54 ± 0.11
December	5	49	960.17 ± 0.29	3	26	959.88 ± 0.09	8	75	960.06 ± 0.18
January 1998	8	148	959.11 ± 0.18	9	138	959.06 ± 0.06	17	286	959.08 ± 0.09
February	8	118	959.24 ± 0.11	9	155	959.09 ± 0.03	17	273	959.16 ± 0.06
March	16	295	959.14 ± 0.09	13	210	958.89 ± 0.08	29	505	959.03 ± 0.06
April	14	194	959.04 ± 0.04	14	195	958.92 ± 0.08	28	389	959.03 ± 0.04
May	13	127	958.99 ± 0.06	9	90	959.00 ± 0.12	22	217	958.99 ± 0.06
June	15	138	959.18 ± 0.06	14	118	959.04 ± 0.07	29	256	959.11 ± 0.05
All period	218	2900	959.22 ± 0.03	137	1730	959.17 ± 0.04	355	4630	959.20 ± 0.02

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