DIURNAL PHOTOMETRIC CONDITIONS AT
TEIDE OBSERVATORY AND LONG-TERM SOLAR
IRRADIANCE VARIATIONS

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Abstract. Monochromatic extinction coefficients at four wavelengths have been obtained over a period of
more than two years at the Observatorio del Teide (Izaña Tenerife) using a full disc, direct sunlight,
quadruple photometer devoted to the detection of integral luminosity oscillations of the Sun. The mean
extinction coefficients (0.13 at 500 nm) show a seasonal variation of about 15%, the best atmospheric
conditions being in winter and autumn. Moreover, in anyone day the extinction coefficient in the afternoon
is always lower than the one in the morning by ~7%. A one-year period fluctuation, with an amplitude
of ~0.035 mag, has been identified in the instrumental magnitudes outside the atmosphere, and is inter-
preted as the variation produced by the different Sun–Earth distance from winter to summer. Finally, the
study made to detect periodic time fluctuations in both, Sun's magnitude and extinction coefficients, has
given null results at levels of ~0.04 and ~1.8%, respectively.

1. Introduction

Photometric measurements allow us to calculate the instrumental magnitude outside the
atmosphere and the atmospheric extinction coefficient, both related to the quality of the
atmosphere at the site where observations are made. In particular, measurements of
atmospheric extinction coefficients show the state of the atmosphere at the site. A low
value of these coefficients mean a high transparency of the sky and their time stability
indicates a good and pure atmosphere with no external contamination, such as aerosol
pollution, dust, smokes, etc.

In this paper, photometric observations to look for long time fluctuations in the
integral sunlight have been used to check the photometric quality of the diurnal sky at
the Observatorio del Teide (Izaña).

2. Observations and Analysis

The instrument used was a full disc, direct sunlight, quadruple photometer built in the
Space Science Department at ESTEC (Jiménez et al., 1987, 1988). Measurements of
solar luminosity are performed simultaneously at four wavelengths with a sampling
interval of 13 s.

Observations have been carried out since the summer of 1984 at the Observatorio del

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Teide (Tenerife) with three major shutdowns: in October 1984, from February to April 1985 and in June 1986 mainly due to lack of manpower. Data up to December 1986 will be analyzed here. From the beginning of the observations to June 1985 only three different wavelengths were employed centred at 680, 1060, and 500 nm, with bandwidths of 10, 20, and 10 nm, respectively. The fourth channel was set up redundantly at 680 nm with an infrared filter in front and was used to assess the instrumental noise. On 22 November, 1985, channel four failed due to problems in the data collection electronics and since it was a redundant channel the decision was taken to continue the run without this information. Later on, in June 1985 a filter centered at 870 nm, and bandwidth of 10 nm, was set up in channel No. 4. Raw data for 17 February, 1986 is shown in Figure 1. The infrared channel (1086 nm) has a strong temperature dependence.

Fig. 1. Raw data obtained from the multichannel photometer for a good day on the 17 February, 1986. Channels Nos. 1, 2, 3, and 4 correspond to 680, 1060, 500, and 870 nm, respectively.
which is seen in the observations. The temperature sensors in the apparatus showed changes of \( \sim 10^\circ \), from summer to winter, in the mean temperature. During any one day a full variation of up to \( 6^\circ \) can be measured from day to night.

The observatory is situated about \( 28^\circ \) N and at a distance of about 350 km from African continent. It offers unique conditions due to the subsiding stable maritime airmass encountered normally above the inversion layer formed between 800 and 1200 m (McInnes et al., 1974). Its altitude, about 2400 m, sites the observatory above the inversion layer for a large fraction of the year. During the summer, invasions of Saharian dust, occur during 35–50\% of the days, but are infrequent during the rest of the year (Sánchez, 1970). Although the dust invasions may create difficulties for some observing programmes (where very constant transparency is required) they do not spoil the seeing. On the contrary in these months the best day-time seeing results can be obtained (Brandt and Wöhl, 1982).

The observation period studied here (from August 1984 to December 1986) can be summarized as follows: out of 860 possible days of observation, 135 days were not used due to absence of manpower to observe or technical maintenance. This leaves 725 possible days of observation out of which 256 were impossible to observe due more than 4 hours to bad weather conditions (clouds, snow, rain, sky extraordinarily absorbent due to dust, etc.). Therefore, there were 469 useful days (64.7\%) from which 26, 29, 29, and 16\% correspond to spring, summer, autumn, and winter, respectively.

In any observing day, the instrumental magnitude \( m \), as defined in the standard astronomical way, is calculated and the airmass the sunlight must cross before reaching the photometer (normalized to unity at zenith) is computed using Bemporad’s formula (Golay, 1974). Then a straight line fit is made and the Sun's magnitude outside the atmosphere and the extinction coefficients are obtained.

Two different procedures have been used: first, a straight line is fitted before and after the Sun crosses the local noon obtaining the above mentioned coefficients in the morning and in the afternoon; second, only one straight line is fitted to the complete daily data series; this gives approximately, the mean coefficients during the day. The standard deviation of the residuals found from subtracting the fitted functions, in the second procedure, to the raw data, vary from \( 10^{-3} \) to \( 10^{-2} \) when the atmospheric transparency varies from very good (coronal) to very bad (absorbent). When a low-frequency filter is applied to the data (cutting any variation higher than 30 min) the fluctuations decrease to \( 10^{-4} \) and \( 10^{-3} \), respectively.

### 3. Extinction Coefficients

The extinction coefficients, obtained using the second procedure, for the different wavelengths in the period observed are shown in Figure 2. These coefficients are very low and constant during the year although in summer there is an increase of the extinction coefficients of about 15\%, and the dispersion of the values are much higher due to the dust.

Mean extinction coefficients \( K(\lambda) \) at the different wavelengths, for spring, summer,
Fig. 2. Extinction coefficients obtained as the slopes of a linear fit to the magnitude-airmass plot, as a function of time for the observed days. Symbols *, +, × represent measurements with channels Nos. 1, 3, and 4, respectively. Measurements from channel No. 2 (1060 nm) show a much higher scatter due to the temperature dependence and they have not been plotted.

autumn, and winter are plotted in Figure 3. About 12% of the points, mainly in summer, were defined as bad and they are not plotted. It is clearly seen that autumn and winter have the highest transparency while the lowest transparency is seen in spring, but in any
Fig. 3. Mean extinction coefficients for the three long-observed channels for each season in the year.

case, the extinction values in all seasons are not very different. For each season the histograms of the number of days with extinction coefficients less than some fixed value are shown for 500 nm wavelength channel in Figure 4. The histograms have their maxima for extinction coefficient values lower than the mean value, having a moderately large queue at high values. These high values are due to days, with less than 5 hours not obtained symmetrically around noon, which are not equally well fitted than the standard ones or some days with very absorbent sky.

In the computation of the extinction coefficients before and after the Sun crosses the local noon, a curious feature is present: the extinction coefficient in the afternoon is always a bit lower that the one in the morning, by approximately 7%. The slope of the morning fit is higher than the one in the afternoon and this feature is always fulfilled (except, for example, in an exceptional day when there has been a strong change in the
Fig. 4. Histograms with the number of days where the extinction coefficient at 500 nm wavelength lies within some fixed values as seen in the graph. The last extinction coefficient interval contains all points higher than the specified value.

transparency due to sudden weather changes). Its interpretation is not clear; one possible explanation might be the fact that before local noon, the sunlight is travelling in the direction of the African continent while in the afternoon the sunlight is above the ocean.

4. Solar Magnitude

The first coefficient of the fit is the magnitude of the Sun outside the atmosphere (in our case, instrumental magnitude because the photometer is not absolutely calibrated).

Figure 5 shows the values for this coefficient for the different wavelengths during the observing period. The main feature is that there is a decrease of the solar magnitude from
Fig. 5. Instrumental solar magnitude outside the atmosphere obtained from the already mentioned fit (see text) for the observed days. Same symbols as in Figure 2.
summer to winter; this wave has a period of one year and is caused by the different Earth–Sun distance from summer to winter. This effect would cause a difference in magnitude, peak to peak, of 0.074% for all wavelengths. To check this, the power spectrum of the solar magnitude, for all measured wavelengths, has been computed (a sine wave fit procedure from 0.01 to 4.0 μHz with steps of 0.005 μHz being the frequency resolution of ~0.01 μHz). In all the spectra a prominent peak at 0.03 μHz is clearly seen with amplitudes of 0.036, 0.032, and 0.019 mag for 500, 680, and 870 nm, respectively. The fit for the red channel is poorer than the others because we have many fewer points. Since there is quantitative agreement the conclusion is that the effect is produced due to the variation Earth–Sun distance during the year.

It has also been attempted to find periodic fluctuations in both, solar magnitude and extinction coefficients, by computing the power spectra of both coefficients at all measured wavelengths. Before computing the power spectra, the badly scattered points were removed. In the solar magnitude spectrum the only significant peak is the one already mentioned and the rest of the spectrum is probably due to the effects of the window function and noise. The spectrum for the extinction coefficient is very similar, there is also a one-year periodic fluctuation caused by the small increase of the extinction in summer and spring already mentioned.

6. Conclusions

The weather conditions at Observatorio del Teide (Tenerife) are exceptionally good with a high percentage of clear days (65%) in the observed period and also of very good days useful for any observing programs. The percentage of very clear photometric days in the period analyzed here are 60, 64, 37, 47% for winter, spring, summer, and autumn, respectively.

The extinction coefficients at the three wavelengths studied here are low and very stable during the year, but show a seasonal variation of less than 15% due to absorbing days caused by dust. The lower mean extinction values are found in autumn and winter. The extinction coefficient in the afternoon is always lower than that in the morning by ~7%; this difference is believed to be caused by the influence of African continent. The variation of the Earth–Sun distance from summer to winter produce a change in the solar magnitude of 0.07 mag detected in the data as would be expected.

Finally the search for periodic fluctuations in the solar magnitude and extinction coefficients has given a null result at the amplitude levels of 0.04 and 1.8%, respectively.

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