On the Results of Measurements of the Direct Sun Radiation Flux by Actinometer and of Maximal Polarization of Sky Brightness in the Solar Almucantar

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Introduction

It is well known that analysis of variations of sky brightness, B, in the visible points to a close correlation between the degree of maximal polarization, P_M, in the solar almucantar (with azimuthal angles in the range 90 ÷ 100°) and atmospheric transparency, p, in the vertical column. Possibilities for assessing aerosol attenuation $\sigma_a = -\ln p_a$ (atm^{-1}) (p_a - transparency of atmosphere due to aerosol) have been found by various authors (Rozenberg 1963; Coulson 1974). However, this method was not sufficiently developed because of the extremely sensitive dependence of P_M on the variations of atmospheric optical properties as manifested by literature sources. The degree of polarization, P, depends on the contribution into sky brightness of multiple scattered light, of surface albedo, and polarization originating from aerosol particles, etc. Simultaneously, many authors found a sufficiently high correlation coefficient, r, between P_M and p_a variations ($r \approx 0.95$) although measurements were carried out in a wide range of air masses, m. Other authors obtained substantially lower values for the correlation coefficient, r.

Currently, work-synchronous estimations of P_M and σ_a are analyzed as obtained under quite low surface albedo ($A \approx 0.2 \div 0.3$). Measurements were carried out between September 12 and October 1, 2001, at Zvenigorod Scientific Station of A.M. Obukhov Institute of Atmospheric Physics of Russian Academy of Sciences (ZSS IAP RAS).

This research seeks to accumulate the data for correlation analysis between σ_a and P_M for various seasons of a year and different values of albedo, A.

Apparatus and Methodology

Relative values of the integral direct solar radiation, S_m, for different air masses, m (spectral range $\lambda = 0.4 \div 4.0$ mcm) were registered continuously by an actinometer. To provide this, an actinometer was installed on a special platform uniformly rotating about Celestial Pole with one cycle occurring every 24 hours. To correct the sun tracking, the sight to the sun was adjusted according to everyday solar decline changing. Data for S_m were collected by a PC-controlled data acquisition system together with the relative values of solar radiation, I_λ, measured by a scanning filter photometer (Shukurov 2001) in four spectral ranges. Interference filters with maximal transmittances at the wavelengths of about λ = 413, 595, 724 and 1005 nm with width near to $\Delta\lambda \approx 10$ nm were used. Measurements of relative sky brightness, B, were carried out within azimuthal angles ranging between 4 ÷ 170° (by $\varphi = 0°$ photometer was directed to the sun).

The degree of polarization, P, was measured by an analyzer (polaroid) mounted on the photometer perpendicular to the line of sight. The polaroid rotation frequency was about 2 Hz.

Variations of polarization degree, P, were analyzed with help of sky brightness data B_λ near wavelength λ = 595 nm being located in the very center of visible light spectral band. It was found that dependence $B_\lambda(\varphi)$ had shown the maximal degree of polarization P_M near azimuth angle $\varphi = 110°$ as a rule.

Usually integral transparency, p, reduced to vertical column measured by an actinometer has been factorized as follows:

$$p = p_{mol}\, p_w\, p_a,$$

Corresponding optical depth σ (atm^{-1}) may be determined as the sum:

$$\sigma = -\ln p = -\ln p_{mol} - \ln p_w - \ln p_a,$$

where p_{mol}, p_w are the contributions into p value due to molecular scattering and water vapor absorption, respectively, and p_a - aerosol attenuation. Precipitable water content w (cm) in the atmosphere was determined from sounding data obtained at the Central Aerological Observatory situated in Dolgoprudny (about fifty kilometers from ZSS IAP). Values for p and σ (atm^{-1}) corresponding to m = 1 were calculated from experimental data $p_m = S_m/S_0$, were S_m и S_0 – solar fluxes near surface and at the top of the atmosphere, respectively. The aerosol thickness σ_a was determined as $\sigma_a = \sigma - \sigma_{mol} - \sigma_w$ from experimental values σ (atm^{-1}) and calculated values σ_{mol} (atm^{-1}) и σ_w (atm^{-1}) ($\sigma_{mol} = -\ln p_{mol}$, $\sigma_w = -\ln p_w$). Water vapor absorption estimation ΔS_w (kW/m^2) necessary for assessing p_w was made by means of McDonald formula: $\Delta S_w = 0.105(mw)^{0.3}$.

Results

Following Rozenberg (1963), the P_M values were determined as follows:

$$P_M = (B_{MAX} - B_{MIN})/(B_{MAX} + B_{MIN}).$$

Daily averaged σ_a and P_M are presented in Table 1. For these days, values w (cm) were obtained from noon aerological soundings.

Comparison between P_M and σ_a are shown at Figure 1. The linear least square approximation of dependence P_M versus σ_a gives the correlation coefficient r = 0.97.

Table 1. Daily averaged σ_a and P_M.

No.	Date	w (cm)	σ_a (atm^{-1})	P_m
1	Sep 12	2.39	0.140	0.54
2	Sep 16	1.86	0.124	0.54
3	Sep 17	2.16	0.150	0.53
4	Sep 18	2.11	0.110	0.57
5	Sep 19	1.90	0.135	0.56
6	Sep 20	1.73	0.149	0.52
7	Sep 23	1.43	0.140	0.53
8	Sep 26	0.76	0.030	0.70
9	Sep 28	1.03	0.045	0.66
10	Oct 01	0.7	0.032	0.72

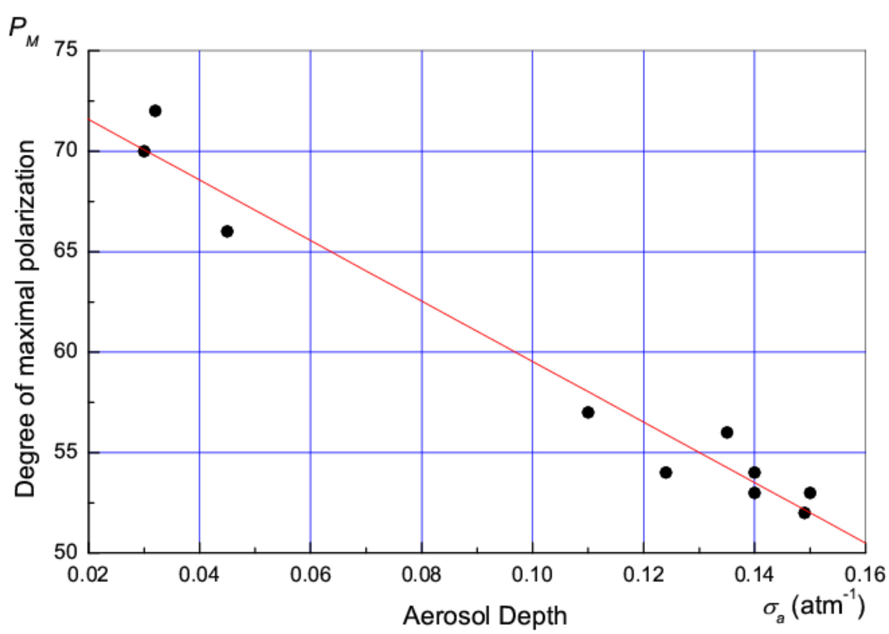

Figure 1. Comparison between P_M and σ_a.

In addition, during one day special attention was paid to P_M measurements in a wide range of air masses $m \approx 2 \div 8$. Results of these measurements (Figure 2) show a weak dependence P_M upon the air mass, m, in accordance with the results by Rosenberg (1963). Significant P_M scattering in the range $m < 2$ was due to the transparency p instability in the first part of a day.

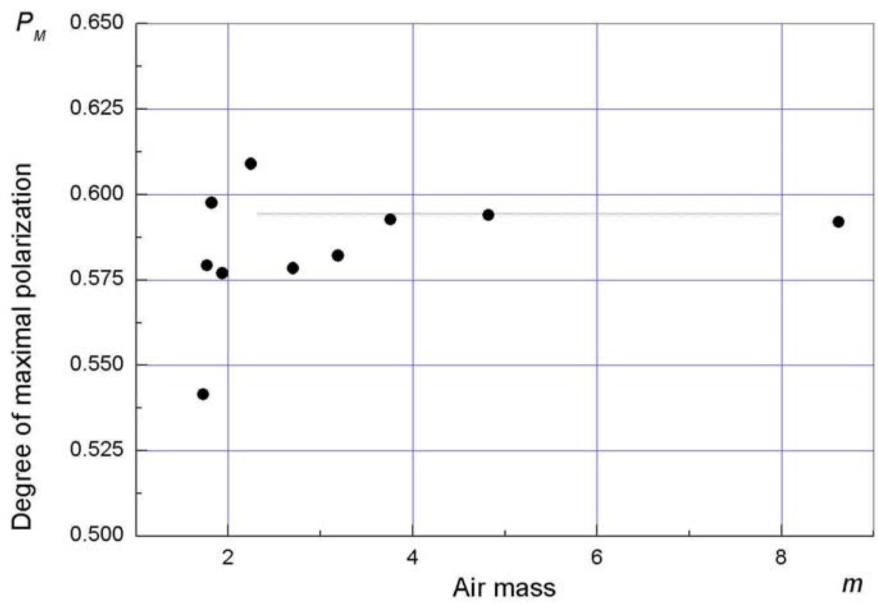

Figure 2. Results of P_M measurements in a wide range of air masses m ≈ 2 ÷ 8.

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