EFFECT OF AEROSOL AND MULTIPLE SCATTERING ON POLARISATION OF SKYLIGHT DURING TWILIGHT

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Keywords: OPTICAL EFFECTS AND REMOTE SENSING OF ATMOSPHERIC AEROSOL, VERTICAL DISTRIBUTION OF ATMOSPHERIC AEROSOL, POLARIZATION OF TWILIGHT SKY, MULTIPLE SCATTERING OF LIGHT IN THE ATMOSPHERE.

INTRODUCTION

A relation between the degree of polarization at the zenith during twilight under cloudless condition and the aerosol content variations in the troposphere and stratosphere was found experimentally in the work of *Shah* (1969). Later papers, *Beiying and Daren* (1988), *Postylyakov et. al* (2001b) and others, discussed an opportunity to determine the vertical distribution of aerosol scattering using twilight measurements. The essential trouble in solution of the raising aerosol inverse problem is allowance for multiple scattering of light, which has the same depolarizing effect like the aerosol. Analytical investigations (*Fesenkov*, 1966, *Ugolnikov*, 1999, *Ugolnikov and Maslov*, 2002) proposed approaches to evaluate a part of multiple scattering light in the polarization. The main goal of this investigation is to separate effects of aerosol and multiple scattering in polarization of skylight, basing on comparison of field observations of polarization and a radiative transfer simulation with account of multiple scattering.

INSTRUMENTATION AND OBSERVATIONS

A few sessions of polarimetric observations, using different instrumentation, were carried out during 1997-2002. Polarimetric measurements were carried out by a scanning photometer for the sun's depth up to 20° under the horizon in July-August of 1997 at Astronomical Observatory of Odessa University (Ukraine). Polarization was observed in solar vertical for the zenith angles from –70° to 70° at 356 nm. The next session was performed by a CCD-camera with polaroid at 360, 440, 550 and 700 nm in July-August 2000 at South Laboratory of Moscow Sternberg Astronomical Institute (Crimea, Ukraine) (see Fig.1). Short-focus optics of the camera allowed to observe the sky up to the zenith angles equal to 15°. Simultaneous observations at Kislovodsk City and High-Mountain (2070 m.a.s.l.) Stations of the Institute of Atmospheric Physics were carried out in 2000-2001 by photometer with rotating polaroid, what allows to calculate the degree of polarization. The observations were performed at 800 nm in the zenith direction. A new series of observations at 550 nm was performed at the South Laboratory in Crimea in November-December 2002, using CCD-camera with medium-focus optics. The maximum zenith angle was equal to 8°.

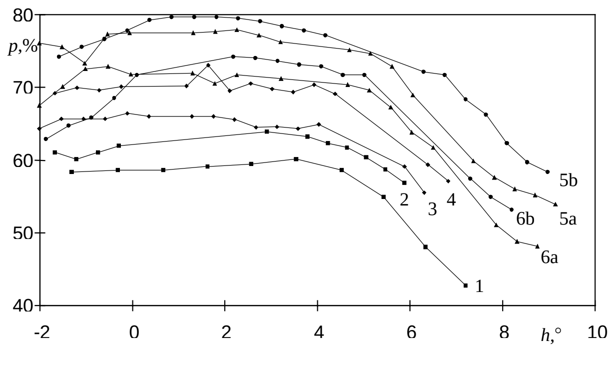

Fig. 1. The dependencies of sky polarization *p* at the zenith on the Sun depression under horizon *h*: 1 – evening, July 31th, 1997, 356 nm, 2 – evening, July 17th, 2000, 360 nm, 3 – morning, July 26th, 2000, 440 nm, 4 – morning, July 28th, 2000, 440nm, 5 – evening, August 4th, 2000, 550 nm (5a) and 700 nm (5b), 6 – evening, August 6th, 2000, 550 nm (6a) and 700 nm (6b).

RADIATION TRANSFER MODEL

A simulation of the twilight polarized radiance was performed by a Monte Carlo radiative transfer model MCC++. The MCC++ model calculates radiative transfer in the spherical shell atmosphere taking into account all orders of scattering, aerosol and Rayleigh scattering, aerosol and gaseous absorption and surface albedo. The code was validated against other models for the twilight geometry of observations (Postylyakov et. al, 2001a). Calculations were carried out for the sun's depth up to 6° under the horizon at wavelengths 360, 440, 550, 700 and 800 nm.

CONCLUSIONS

The influence of aerosol scattering had turned out to be insufficient for most part of performed observations at 356-550 nm (under cloudless condition), that makes multiple scattering exact estimations possible. From 700 nm aerosol scattering becomes more sufficient. Thus, to separate aerosol and multiple scattering at red wavelengths, it is necessary to use radiative transfer simulation.

The contribution of single scattered light in the total twilight sky background at the zenith is equal to about 40% for 360 nm, 60% for 440 and sometimes reaches 70% for 550 nm. This fact is the reason of lower sky polarization at shorter wavelengths. The ratios remain almost constant until the sun's depth under horizon 4-5°, when the part of single scattering rapidly decreases, and the sky polarization falls (see Fig. 1). At the sun's depth about 10° single scattered light completely disappears on the multiple scattered background.

Red wavelengths are more informative for aerosol sounding. A theoretical error analysis shows that measurements carried out at 800 nm with the Kislovodsk instrument has accuracy enough to detect a 2-km aerosol layer, which exceeds background concentration by more than 50% at 12-25 km or by 60% at 5-45 km, or detect a 5-km aerosol layer, which exceeds background concentration by more than 25% at 18-20 km or by 40% at 11-45 km. Notice that, in periods of the enhanced aerosol concentration (after powerful volcanic eruptions) this retrieval error may become less than 10%.

Basing on the comparison, an empirical model of degree of polarization during twilight for wide spectral region is also proposed. The empirical model can be used for optimal choice of wavelengths for twilight measurements of the polarized radiance for the determination of the aerosol vertical distribution.

ACKNOWLEDGEMENTS. This work was supported by the Russian Foundation for Basic Research under grants 00-02-16396, 01-05-64546, 01-02-06247 and 02-02-06140.

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