

Investigations of Atmospheric Aerosol Based on the Polarization Measurements of the Twilight Sky

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Optical measurements of the sky background during the twilight period are the effective tool for the detection and investigations of aerosol in the different layers of the atmosphere. Ascension of Earth's shadow above the observer with the depression of Sun leads to the increase of the effective altitude of the solar emission scattering in the atmosphere [1]. Having conducted the sky background measurements during the whole twilight period, we made the vertical scan of the atmosphere and build the profile of trace gases and atmospheric aerosol from the troposphere to mesosphere.

The basic problem of the twilight method of atmosphere investigations is the large contribution of multiple scattering [2]. This value was difficult to estimate through the whole XX century. The exact mathematical models had appeared just recently [3].

The possibilities of twilight method sufficiently expand if the sky background polarization is also measured. First, it helps to separate the multiple scattering due to the difference of polarization properties of this component. The idea of the method was suggested in [4] and was developed in [5,6]. The results were in good agreement with the numerical calculations for standard aerosol models in the troposphere [7]. Second, polarization data expand the information about the atmospheric aerosol and allow to investigate its microphysical properties. The idea was applied to the dense and variable tropospheric aerosol in [8].

The background level of stratospheric aerosol is usually low. In the polar regions the polar stratospheric clouds (PSC) can appear. In other locations the increased level of stratospheric aerosol is observed after the strong volcanic eruptions, when the large amount of sulfur dioxide (SO_2) reaches the stratosphere, oxidizes to the sulfur acid (H_2SO_4) and condensates to the sulfate aerosol particles. The most powerful volcanic eruption in the recent decades was the Pinatubo eruption in 1991. During the following 3-4 years the stratosphere was globally polluted, but after that the clear stratosphere period had started.

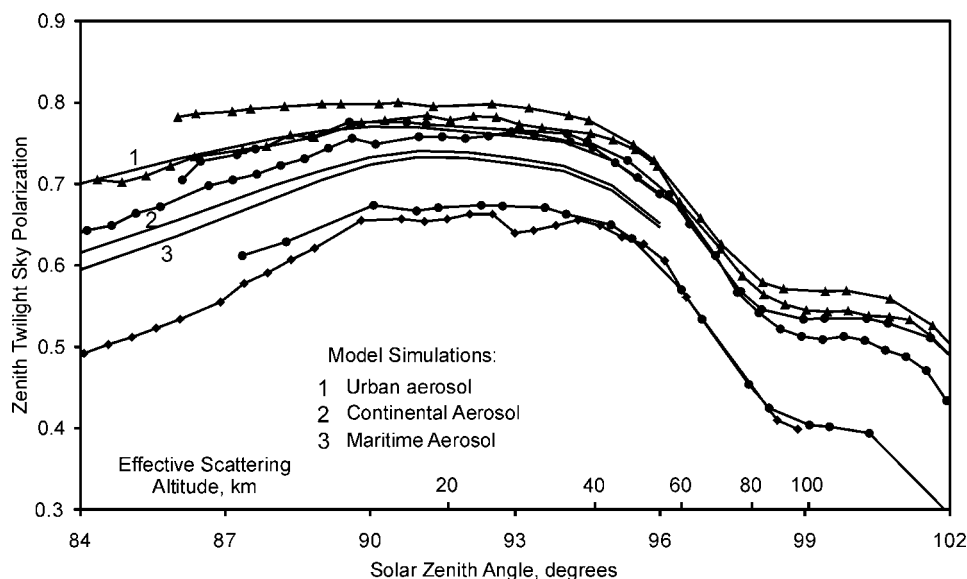


Figure 1. Theoretical and observational dependencies of zenith twilight sky polarization on the solar zenith angle (525 nm, clear stratosphere period).

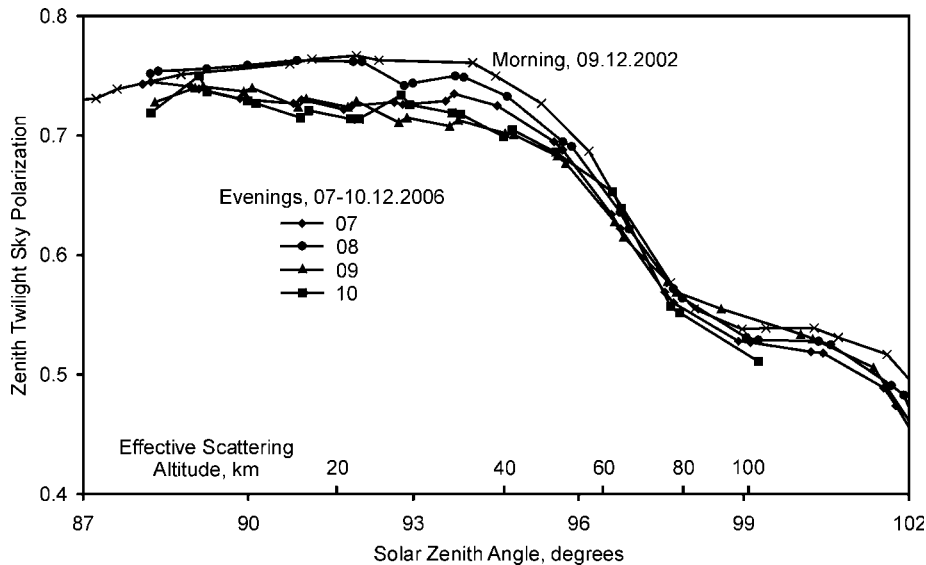


Figure 2. Dependency of zenith twilight sky polarization on the solar zenith angle with the effect of stratosphere depolarization in December, 2006.

Figure 1 contains the dependencies of the twilight background polarization in the zenith on the solar zenith angle or effective scattering altitude for different years (2000-2003) and seasons in the clear stratosphere period. These dependencies are obtained from the wide-angle CCD-measurements in Crimea in wide spectral band with effective wavelength 525 nm. The graph also contains the results of numerical simulations for the gaseous atmosphere and three standard tropospheric aerosol models with the background stratospheric aerosol. We see that for solar zenith angle more than 90-91 degrees, when the effective single scattering occurs above the troposphere, all observational and theoretical curves are just shifted one from another as a whole. Variations of twilight sky polarization are the same in the light and dark stage of twilight, when multiple scattering dominates. So, the nature of these changes is related with multiple scattering. Depolarization caused by the stratospheric aerosol is not observed.

In October, 2006, the eruption of Rabaul volcano in New Guinea had started. The eruption products reached the stratosphere and began to expand there. Increased level of stratospheric aerosol was detected by the lidar station in Tomsk, Russia, even in October [9]. Figure 2 shows the dependencies of moonless sky polarization in December, 2006, compared with the one in the same season in 2002. We see that the polarization is almost the same in the light and dark twilight, but there is the depolarization effect when the effective scattering occurs in the stratosphere. Analysis of observable parameters (intensity, polarization and their gradients along the solar verticals) shows that the effect is related with the additional scattering component in the stratosphere. The method developed in [10] gives the polarization value of stratospheric aerosol scattering by the angle 90 degrees (0.28 ± 0.03), the ratio of aerosol and molecular scattering in the stratosphere (varying from 0.1 to 0.2). Last value is in good agreement with the lidar backscattering data [9].

The same analysis can be used to detect the dust and aerosol in the mesosphere. This atmosphere layer can contain the noctilucent clouds and be bombarded by the meteoric dust. The strongest meteor shower in the recent years was Leonids having the outbursts from 1998 til 2002 after the perihelion of parent comet 55P/Temple-Tuttle in 1998. The last double-peaked storm was predicted in [11] and observed at November, 19, 2002. During the first maximum with Zenithal Hourly Rate about 2500 the shower radiant was high above the horizon at the observation place in Crimea, providing the good conditions for the meteoric dust inflow to the mesosphere [12].

Figure 3 shows the same dependencies of the twilight sky polarization on the solar zenith angle for the period of late November and early December 2002, the moonlight scattering and multiple scattering variability are reduced. We see the effect of twilight sky depolarization at November, 21, 2002, for the scattering altitudes above 90 km. The effect is related with the meteoric dust in the mesosphere.

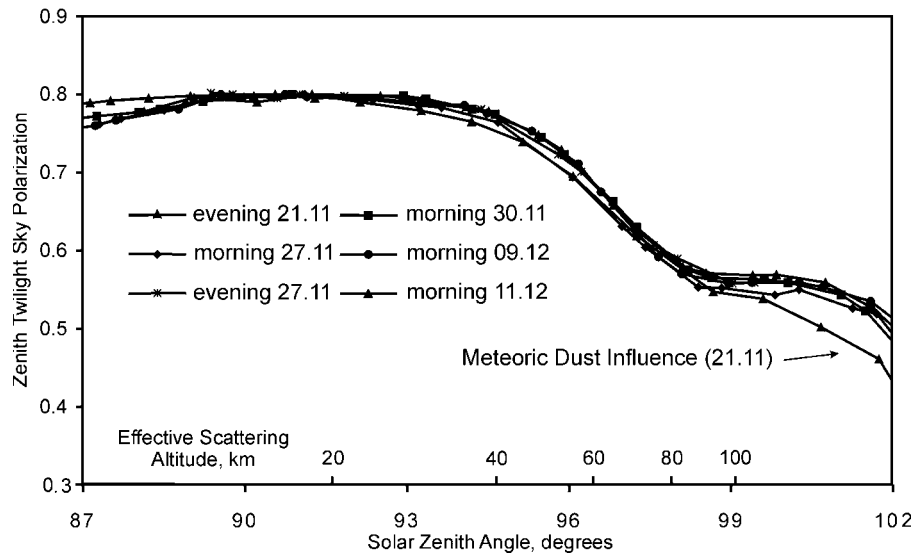


Figure 3. Dependency of zenith twilight sky polarization on the solar zenith angle with the effect of meteoric dust in November, 2002.

The way to improve the twilight investigations of the atmosphere is the idea of the network installation for the twilight photometric and polarization measurements. Aerosol remote sounding above the large territories will make possible the dynamical investigations of production, transportation and destruction of different kinds of aerosol in the atmosphere.

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