On Correction of Diffuse Radiation Measured by MFRSR

T. B. Zhuravleva
Institute of Atmospheric Optics, SB RAS
Tomsk, Russia

M. A. Sviridenkov and P. P. Anikin
A. M. Obukhov Institute of Atmospheric Physics, RAS
Moscow, Russia

Introduction

The multi-filter rotated shadowband radiometer (MFRSR) provides spectral direct, diffuse, and total horizontal solar irradiance measurements. Because the MFRSR's receiver has a non-Lambertian response, for a correct interpretation of measured radiation an angular correction is needed. Such a correction of MFRSR data is performed for direct solar radiation, whereas uncertainty exists concerning the diffuse irradiance, whose spatial distribution is not known a priori. The data on diffuse irradiance can be used to calibrate the instrument (Alexandrov et al. 1998) and estimate the aerosol single scattering albedo (Anikin et al. 2002). Thus, errors in diffuse irradiance may lead to erroneous calibration constants and estimates. In this study we estimated the errors in measured diffuse radiation caused by imperfect cosine response of the receiver and explored the possibility of correcting the measurement data based on results of numerical Monte Carlo simulations.

Model Computations

In numerical experiments, we used the model of the aerosol-molecular plane-parallel atmosphere and the assumption of horizontally homogeneous underlying surface, reflecting incident radiation according to the Lambert law. The map of sky brightness was calculated by the method of local estimate. The step in zenith angle was 1°. For each zenith angle, the sky brightness was calculated at 84 azimuth angles. In our simulations, we used four model aerosol size distributions (three power law functions with Junge exponents b equal to 3, 4, 5, and one lognormal function with a median radius of 0.05 μm and the variance of the logarithm of radius equal to 0.6). Scattering phase functions were calculated at a wavelength of 671.6 nm, assuming the refractive index to be 1.45. The asymmetry factors of phase functions were 0.75, 0.67, and 0.53 for the power law distributions, and 0.70 for the lognormal function. Calculations were made for two values of the surface albedo A, 0, and 0.4. To simulate MFRSR measurements, the sky brightness for each zenith and azimuth angle was multiplied by the correction factor taken from the angular correction tables for the MFR head S/N 425. Then, the true and disturbed sky brightness was integrated over hemisphere to obtain the "real" and "measured" horizontal diffuse irradiances.

Discussion

The calculations show the underestimation of the diffuse radiation measured by MFR head S/N 425 within 2% to 4%. The ratio R of corrected/non-corrected diffuse irradiance displays weak dependence on solar azimuth and zenith angles, surface albedo, phase function asymmetry factor, optical depth, and wavelength. Most pronounced among these are the dependences on asymmetry factor, aerosol optical depth, and solar zenith angle (SZA). Figures 1 and 2 show the dependence of the ratio "true"/"measured" irradiances on the SZA for different aerosol models and optical depths τ at wavelengths of 497.3 nm and 671.6 nm. The maximum of the ratio is observed at zenith angles about 60° to 70°. The ratio R slightly decreases with increasing aerosol optical depth. Figure 3 illustrates this tendency. From our calculations it follows that the data on diffuse irradiance, measured by MFRSR, can be corrected based on calculations using the angular correction table for the specific instrument. With the availability of the aerosol optical depth and asymmetry factor of the scattering phase function, this correction can be made more precise.

Underestimation of the diffuse irradiance leads to underestimation of the single scattering albedo using the diffuse/direct method. Figure 4 shows the results of retrieval of the single scattering albedo of non-absorbing aerosol from the non-corrected data on diffuse irradiance. Simulations were made for three values of the aerosol optical depth at the wavelength of 497.3 nm equal to 0.1, 0.2, and 0.3, Angstrom's exponent of 1, asymmetry factor of 0.67, and SZA of 60°.

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Corresponding Author

M. A. Sviridenkov, misv@mail.ru

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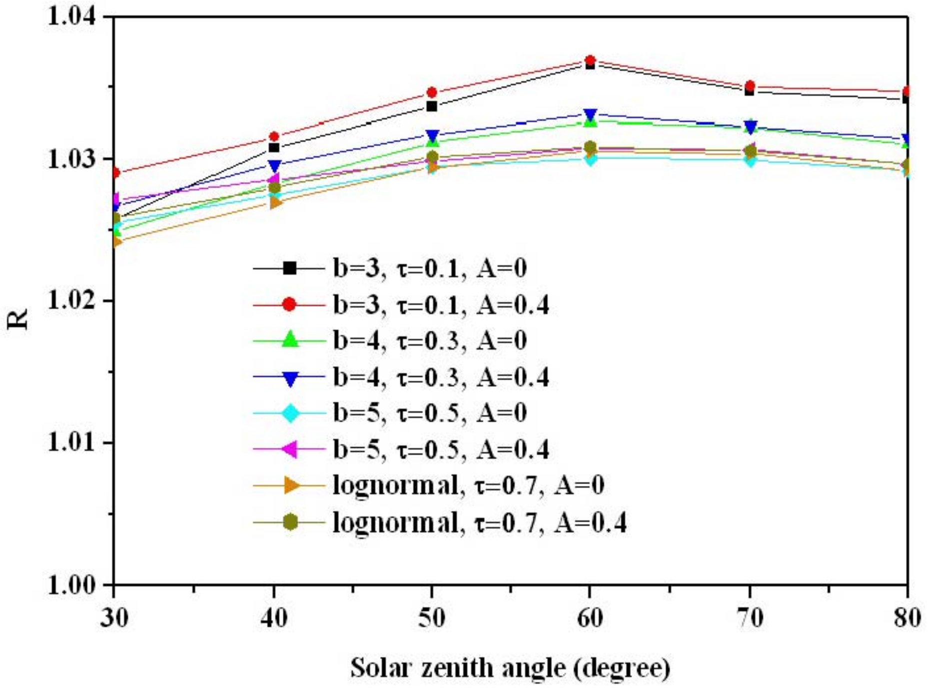

Figure 1. Dependences of the ratio R on SZA at a wavelength of 497.3 nm.

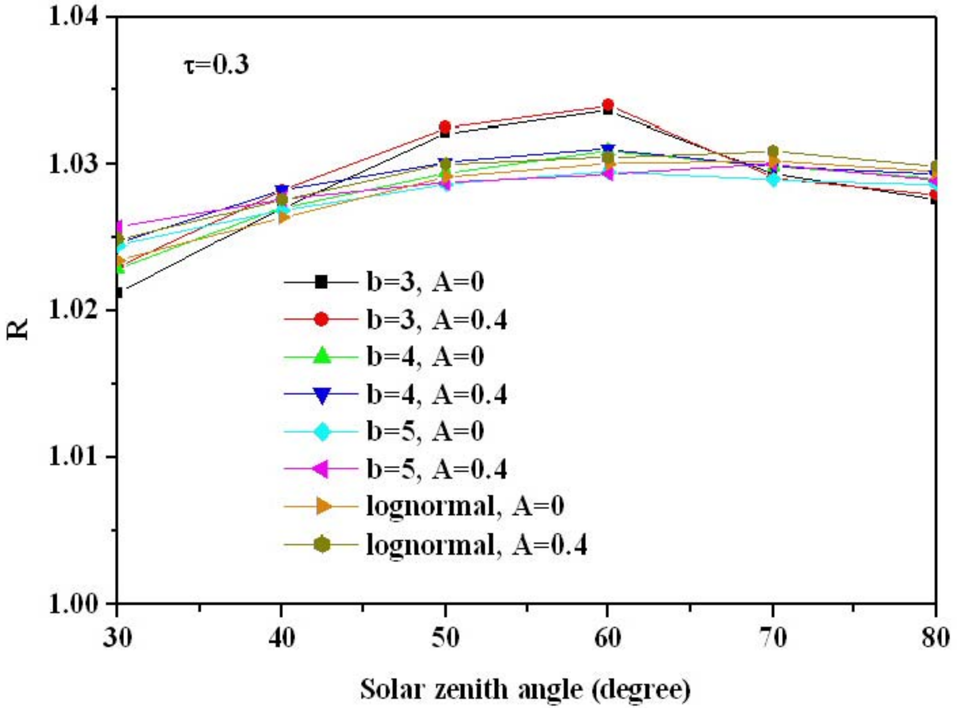

Figure 2. Dependences of the ratio R on SZA at a wavelength of 671.6 nm. Aerosol optical depth τ = 0.3.

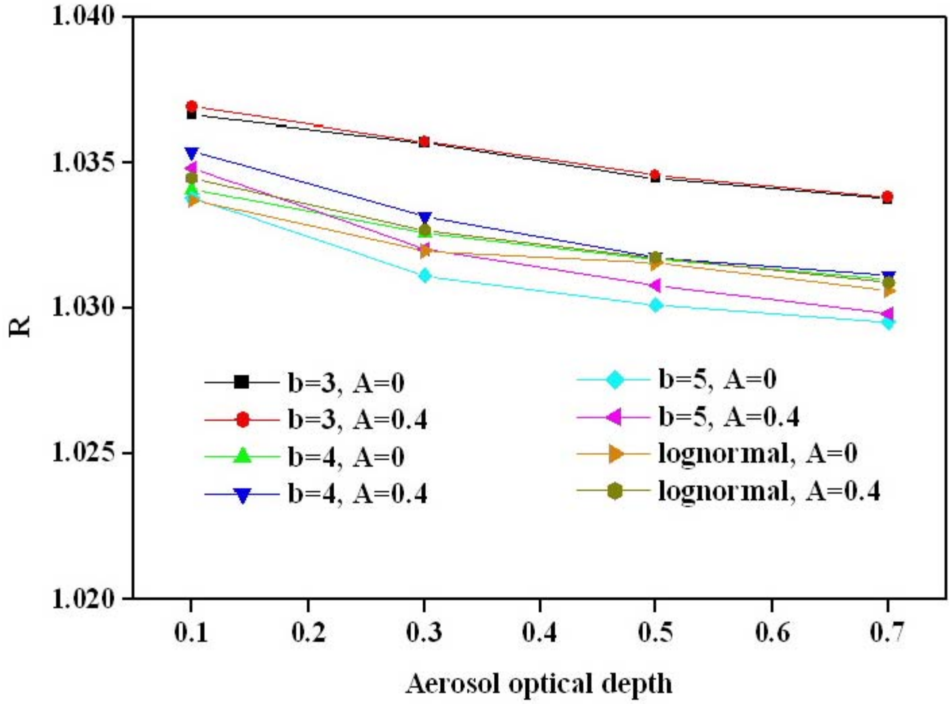

Figure 3. Dependences of the ratio R on aerosol optical depth at a wavelength of 497.3 nm.

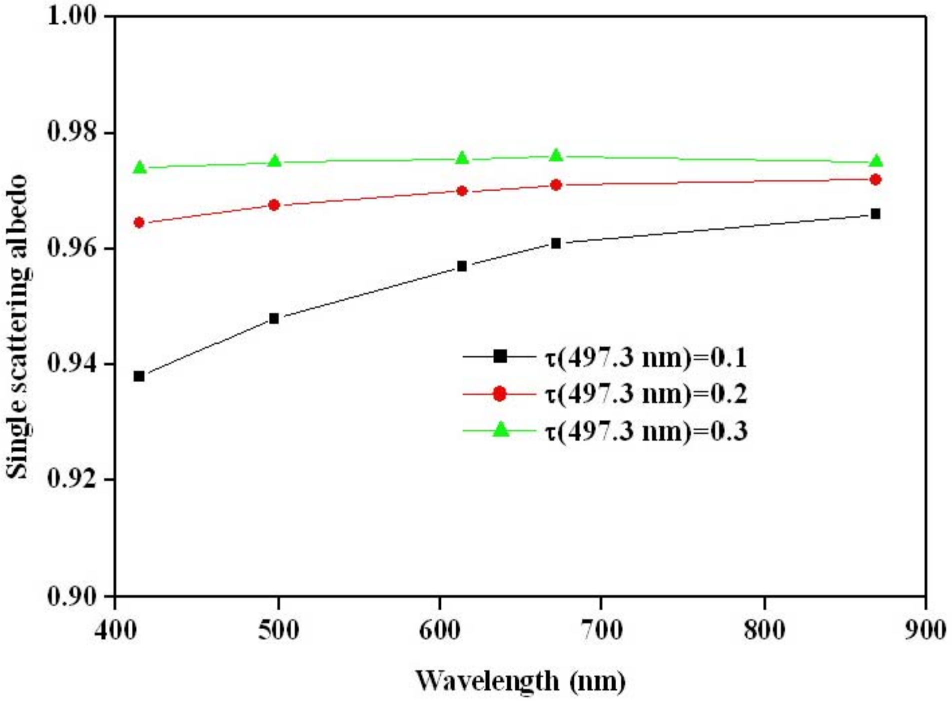

Figure 4. Erroneous retrieval of the "single scattering albedo" of non-absorbing aerosol from non-corrected data on diffuse irradiance.