An Instrumentation Complex for Atmospheric Radiation Measurements in Siberia

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Introduction

The instrumentation complex is described, which has been prepared for radiative experiments in the region of Tomsk (West Siberia). The complex consists of three groups of devices to measure (a) the characteristics of the total downward radiation; (b) the most variable components of the atmospheric transparency directly affecting the income of radiation (aerosol optical depth [AOD], total content of water vapor, ozone, etc.); and (c) aerosol and meteorological parameters of the near-ground layer of the atmosphere. The results of spectral measurements of the direct and scattered solar radiation are used to reconstruct the aerosol microstructure in the atmospheric column and compare it to the analogous characteristic of the near-ground layer.

Instruments

The first group of instruments includes the devices designed to measure of the radiative characteristics (Table 1): MS-802 pyranometer, MS-202 pyrgeometer, and MS-53 pyrheliometer (EKO Instruments Trading Co., Ltd., Japan). The self-designed automatic solar tracker is used for guidance of the pyrheliometer MS-53 to the Sun. Another device, the rotating shadowband radiometer MFR-7, is capable of determining the spectral fluxes of incoming radiation (global and diffuse) and the AOD of the atmosphere. The data obtained by these aforementioned devices are collected and recorded using the standard data acquisition system YESDAS-2 (YES, INC., USA).

Table 1. Devices for radiation measuring

Model	Characteristic	Spectral Response
High Precision Pyranometer MS-802	Global Solar Radiation	305 ~ 2800 nm
Pyrheliometer MS-53	Direct Solar Radiation	305 ~ 2800 nm
Pyrgeometer MS-202	Longwave Radiation	4 - 50 μm
Shadowband Radiometer MFR-7	Spectral Radiation and AOD	415, 500, 615, 673, 870, 940 nm

The second group of instruments (Table 2) includes the sun photometers: the CE-318 photometer (0.34 to 1.02 μm) operation in AERONET (http://spamer.gsfc.nasa.gov); the SP-4 multi-wavelength sun photometer (0.31 to 4 μm) operating the-year-round; and the SP-5 scanning photometer (0.425 to 2.32 μm) for measuring the aerosol scattering phase function. The specifications of the SP-4, 5

Table 2. Main characteristics of the sun photometers.

Model	Radiation	Spectral Response	Characteristics
CE 318 (AERONET)	Direct and Diffuse	340, 380, 440, 500, 675, 869, 936, 1020 nm	AOD, H_2O column amount, size distribution, phase function, ASS
SP - 4 (IAO, Russia)	Direct	309, 324, 340, 371, 408, 438, 475, 500, 547, 675, 871, 938 nm, 1.05, 1.25, 1.56, 2.14, 4 μm	AOD, O_3 and H_2O column amount, size distribution
SP - 5 (IAO, Russia)	Direct and Diffuse	425, 438, 485, 550, 674, 873, 939 nm, 1.06, 1.2, 1.6, 2.19, 2.32 μm	AOD, H_2O column amount, phase function, size distribution

photometers and the techniques for determining the aerosol characteristics are considered by Kabanov et al. (2001a,b). Two photometric sites, in the suburb of Tomsk and in the forest region 60 km from the city, are arranged for the radiative experiments. The arrangement of the instrumentation complex is shown in Figure 1.

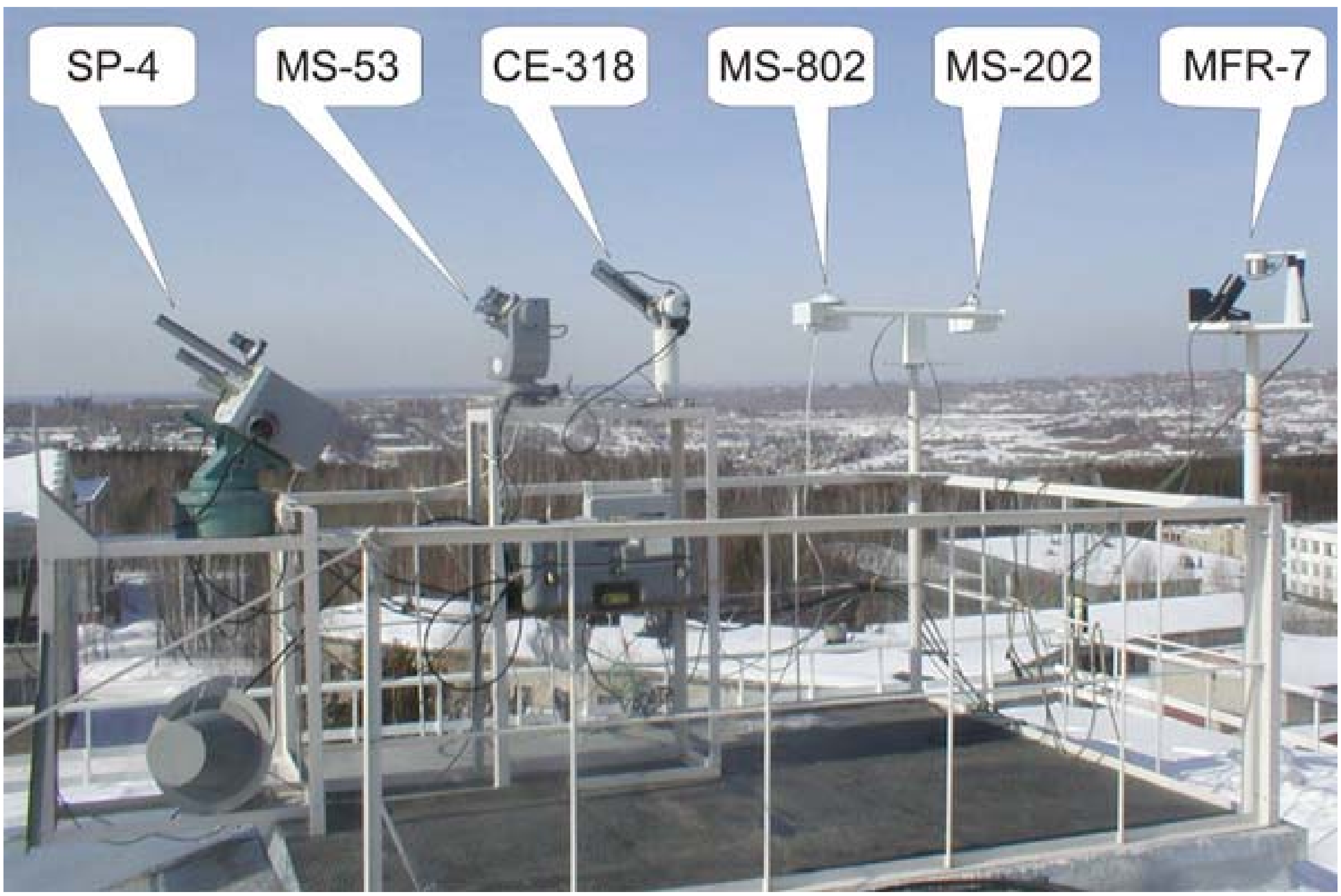

Figure 1. External view of the radiative complex at the photometric site.

The specifications of the third group of devices destined for measuring the aerosol characteristics in the near-ground layer of the atmosphere are presented below.

Multi-wavelength meter of transparency of the near-ground layer of the atmosphere consists of two filter photometers operating simultaneously in the wavelength ranges 0.44 to 1.06 μm and 1.06 to 12 μm. Measurements are carried out on the 415-m long near-ground path with reflection (the total length is 830 m). The reflector for both photometers is the mirror cat-eye. Time of recording a transparency spectrum of the atmosphere in 20 spectral channels is about 5 minutes. The whole process of measurements is completely automated and is controlled by a personal computer. The total extinction coefficients are calculated from the measured values of the atmospheric transmittance, then the aerosol extinction coefficients are selected from them by the method of multiple regression.

The aerosol monitoring station includes the following devices: a nephelometer to measure the aerosol scattering coefficient at $\lambda = 0.41$, 0.51 and 0.63 μm and the parameter of aerosol condensation activity when artificially humidifying the aerosol sample; an aethalometer for measuring the mass concentration of soot in aerosol particles; and a photoelectric counter for measuring the number density and particle size distribution in the diameter range of 0.4 to 10 μm. The nephelometer is calibrated by the molecular scattering of pure air and different gases. Its sensitivity is about 0.01 km^{-1}. The aethalometer detects the diffuse attenuation of light from the layer of aerosol particles that settle on a filter and measures the mass concentration of soot with sensitivity of 0.1 $\mu g/m^3$ in the range up to 110 $\mu g/m^3$. The device is calibrated using the results of simultaneous optical and gravimetric measurements of soot aerosol from 50 to 200 nm generated at pyrolysis of butanol vapor in the nitrogen atmosphere at temperature of 1150°C. The photoelectric counter measures the particle size distribution in the number density range up to 300 cm^{-3} with a mean error of about 20%. The data obtained at the aerosol monitoring station are used for the analysis of the variability of the mass concentrations of aerosol and soot in the near-ground layer of the atmosphere and the peculiarities of their transformation under the effect of geophysical factors.

Results

Preliminary investigations were carried out to test the techniques for a winter radiative experiment. Examples of the diurnal variability of the integral and spectral characteristics of the incoming radiation are shown in Figures 2 and 3.

The use of several types of solar photometers will increase the information capacity of the experiments, in particular, for obtaining the data on AOD in the wide wavelength range with better reliability. Comparison of the data on diurnal variability of AOD and columnar water vapor of the atmosphere obtained from different photometers and calculation techniques is shown in Figures 4 and 5. Mean spectral dependencies obtained by SP-4 and CE-318 are illustrated in Figure 6. Differences in the data do not exceed the error margin for determining the sought characteristics. The differences in spectral AOD and the columnar water vapor do not show a large inaccuracy between the two devices.

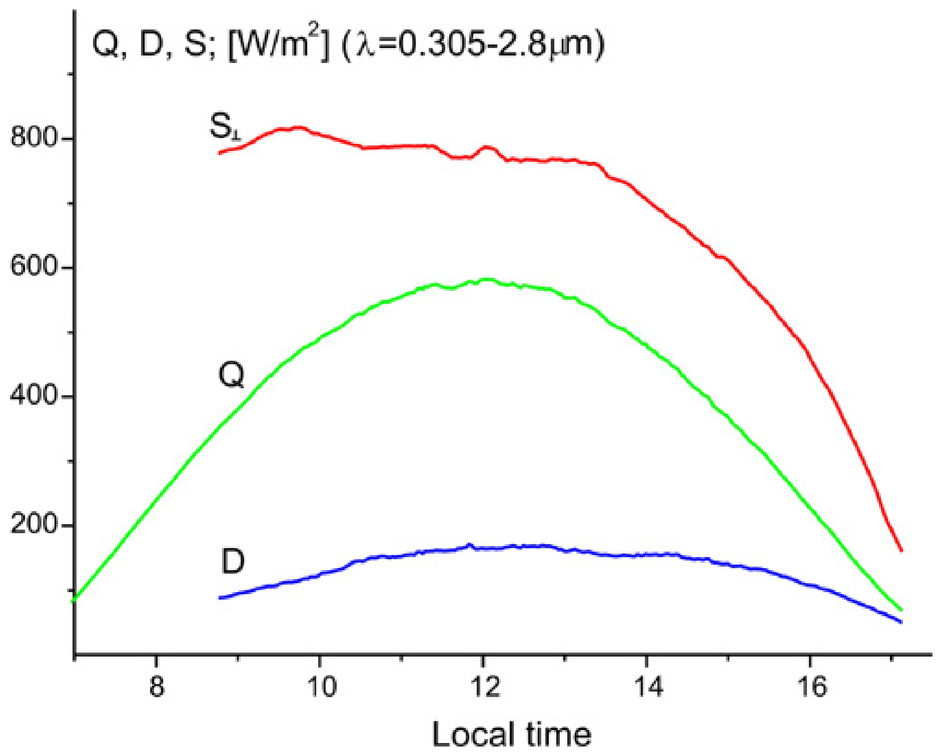

Figure 2. Diurnal plots of total (Q), direct (S), and diffuse (D) radiation (MS-53, 802; March 17, 2003).

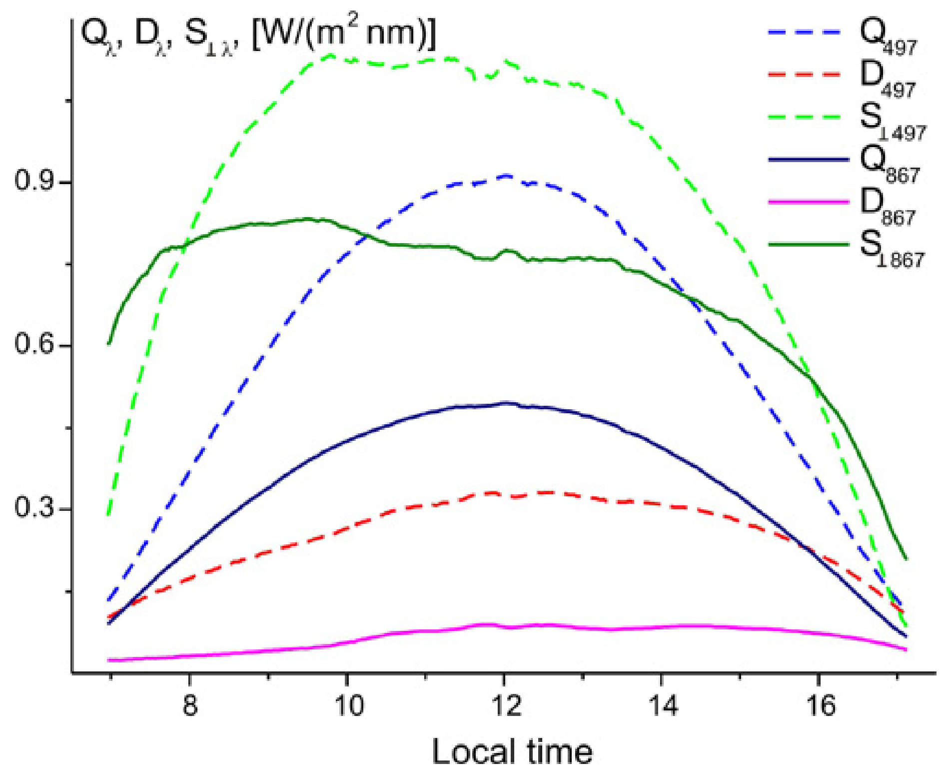

Figure 3. Diurnal plots of total, direct, and diffuse spectral radiation (MFR-7; March 17, 2003).

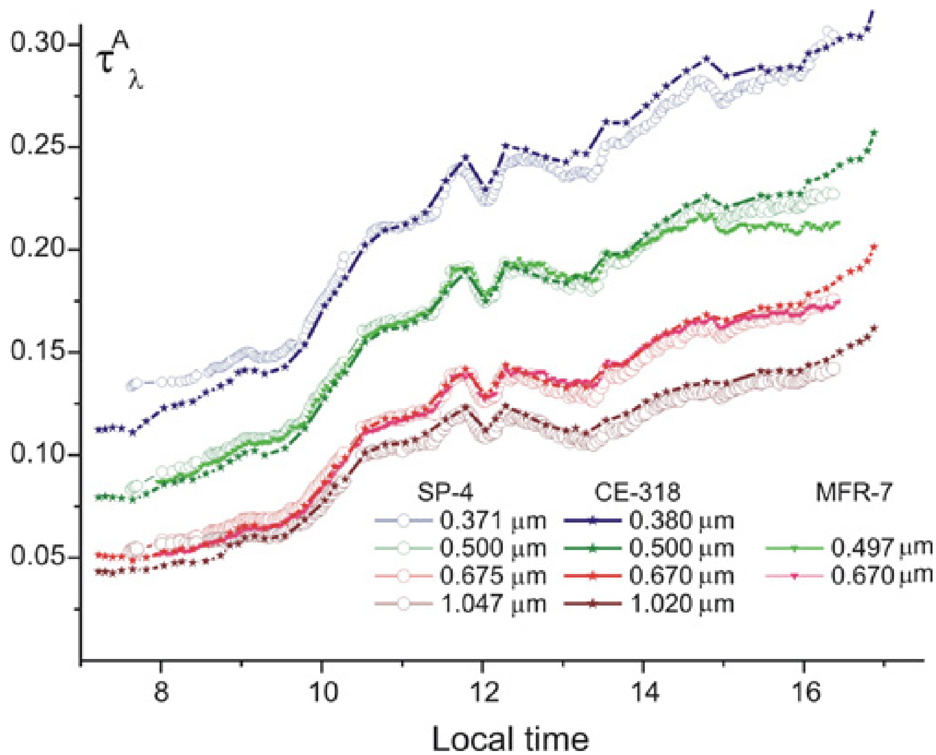

Figure 4. Daily changes of spectral AOD of atmosphere (SP-4, CE-318, MFR-7; March 17, 2003).

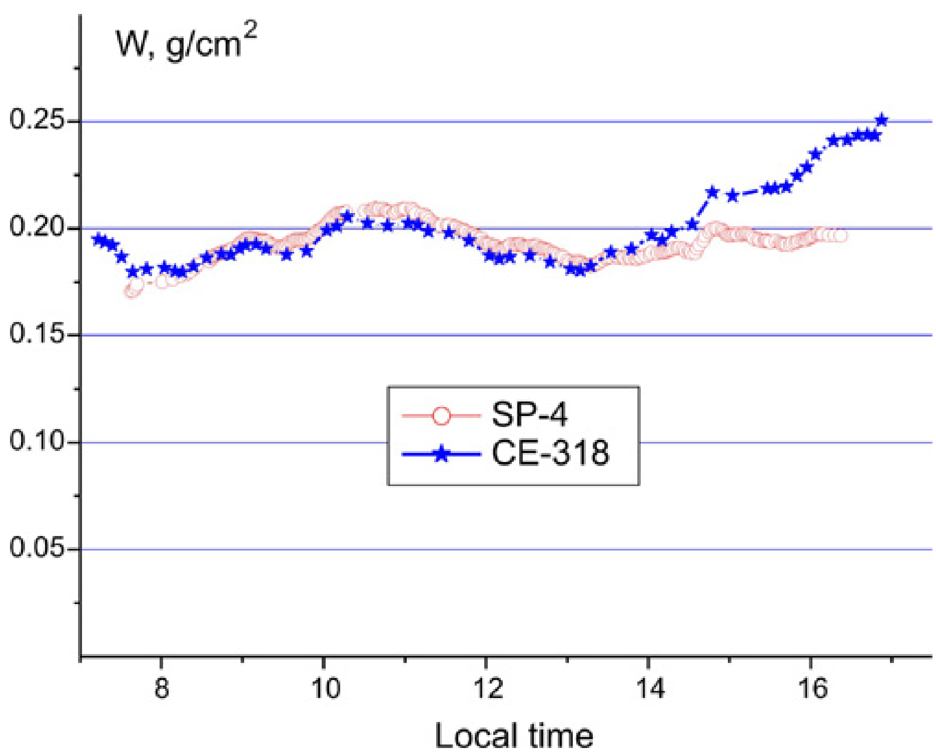

Figure 5. Daily changes of atmosphere columnar water vapor (SP-4, CE-318; March 17, 2003).

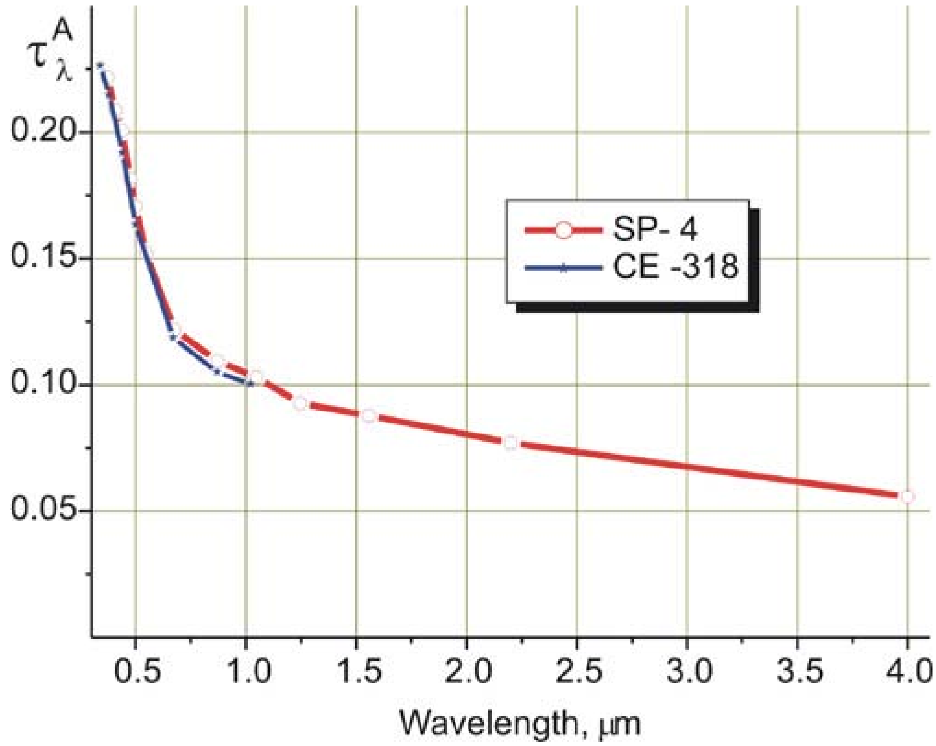

Figure 6. Spectral dependences of AOD obtained by SP-4 and CE-318 (March 17, 2003).

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