Multiwavelength, Multifield of View Solar Aureole Photometer

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Introduction

A new instrument for the investigation of optical characteristics of semi-transparent clouds, a multiwavelength, multifield of view (MWMFOV) solar aureole photometer, was designed and constructed at the Institute of Atmospheric Physics, Russian Academy of Sciences. The MWMFOV instrument includes six photometers with field of views (FOVs) from 1.6° to 9.8°. The effective measurement wavelengths are 0.46 µm, 0.54 µm, 0.62 µm, 0.82 µm, and 1.15 µm. The experimental data are stored into a computer. The technique for retrieving the cloud particle size distributions from the spectral extinction measurements, taking into account the scattered FOV solar radiation, was adopted by MWMFOV measurement data set and checked by model computations. The observations of the different cloud types were held at the Zvenigorod Scientific Station near Moscow. The results of observations and size spectra of the semi-transparent clouds obtained are presented.

Description of the Instrument

The MWMFOV photometer is designed for spectral measurements of the combined solar radiation transmission and near-forward scattering by semi-transparent clouds. The instrument includes six photometers with FOVs from 1.6° to 9.8°. FOVs are formed by six tubes with diaphragms. Silicon photodiodes are used as photodetectors. A disk with filters of colored glass rotates in front of the photodiodes with angular velocity about 10 r.p.s. The effective wavelengths of the filters are 0.46 µm, 0.54 µm, 0.62 µm, 0.82 µm, and 1.15 µm. The spectral half-width of the first four filters is near 15 nm and the last is -30 nm. Five signals for different wavelengths are picking off one photodiode during one revolution. Thus, the period of one measurement cycle (30 readings) is less than 1 second. The MWMFOV photometer is mounted at the active tracking system, which provides solar tracking for cloud optical depth up to several units with angular error in the direction to the sun in less than 3 minutes. Readings are synchronized with the position of the disk by using LED-photodiode pairs through the openings in the disk. The electronic part of the instrument includes amplifiers and analog-digital converters.

Operating and Primary Data Processing

Measurements with the MWMFOV photometer were carried out in the summer of 1997 at the Zvenigorod Scientific Station of IAPh near Moscow. Measured cloud optical depth τ_m is determined as the logarithm of the ratio of measured clear-sky direct solar irradiance compared to that of a cloud covering the solar disk. Clear-sky irradiance is found by interpolation of signals measured in breaks between clouds. Measured optical depth τ_m is always less than actual value τ, due to the input of the scattered light into the FOV of photometers. The ratios of τ_m for different FOVs and wavelengths depend upon particle sizes and are used for the estimation of the cloud microstructure.

The program guiding the photometer operates in two regimes. In the recording mode, it allows you to choose continuous or discrete records with a given time step, the number of averaged realizations, and the type of displayed information (digital, graphic, or combined). In the processing mode, the program calculates cloud optical depths τ_m, correlation and regression coefficients for each pair of channels. Correlation and regression analysis is carried out for range of optical depths between two markers defined by the operator. Big values of correlation coefficients (> 0.99) indicate stability of cloud microstructure, and in such cases, the regression coefficients, as well as instantaneous values of τ_m, can be used for the estimation of cloud size distributions. Rough estimates of the particle's effective radii can be obtained by comparing measured regression coefficients (i.e., the ratios of the τ_m) to those calculated for a set of narrow size distributions. The minimal root mean square (rms) between measured and calculated τ_m points out the quasi-monodispersed size distribution with closest cloud optical characteristics. For such estimations, the function "Inversion" is provided in the program. The result of such "library inversion" is shown in Figure 1 for cloud type Ac.

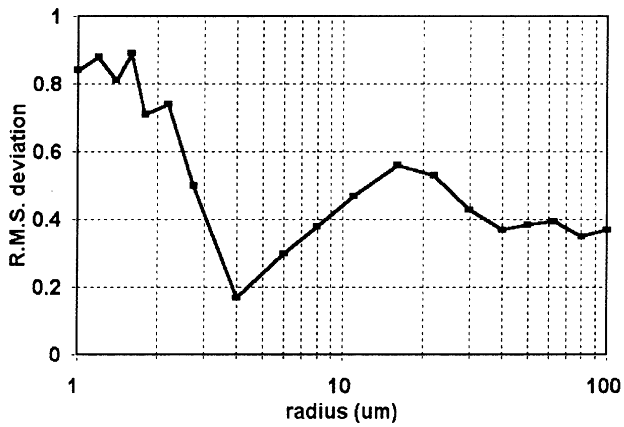

Figure 1. Rms estimation of the cloud particle size.

Retrieval of the Cloud Microstructure

For cloud optical depth less than several units, the measured τ_m (λ,α) (α - FOV) is connected with cross-section size distribution S(r) by linear integral equation (Golitsyn et al. 1997):

$$\tau_m(\lambda,\alpha) = \int Q(\lambda,\alpha,r)S(r)dr \qquad (1)$$

or in discrete form:

$$\tau_m(\lambda,\alpha) = \Sigma Q^d(\lambda,\alpha,r_i)S(r_i) \qquad (2)$$

The values of $Q^d(\lambda,\alpha,r_i)$ normalized to Q^d for λ = 0.82 µm and $\alpha = 1.6^0$ are presented in Table 1 for several r.

In the shortwave region, cloud extinction displays weak spectral dependence. It follows from data in Table 1 that input of the scattered lights significantly increases the sensitivity of the measured spectral and angular dependencies of $\tau_m(\lambda,\alpha)$ to the particle size.

Table 1. Normalized kernel functions.

	λ = 0.46 um		**λ = 1.15 um**	
r, µm	**$\alpha = 1.6^0$**	**$\alpha = 9.8^0$**	**$\alpha = 1.6^0$**	**$\alpha = 9.8^0$**
1	0.656	0.568	1.062	1.019
2.2	0.814	0.548	0.710	0.654
6	0.889	0.569	1.071	0.690
16	0.797	0.686	1.156	0.748
22	0.906	0.788	1.186	0.837
30	0.937	0.844	1.109	0.885
50	0.946	0.880	1.046	0.908
100	0.971	0.925	1.030	0.941

The modified iterative algorithm of Twitty (1975) was used for the inversion of Eq. (2). The method was checked for the MWMFOV data set on model size spectra. Satisfactory agreement was found between input and recovered size distributions in the size range: 2 µm to 50 µm. The example of model inversion is given in Figure 2. The results of the inversion of experimental data are shown in Figure 3 for volume distribution V(r) = 4/3rS(r).

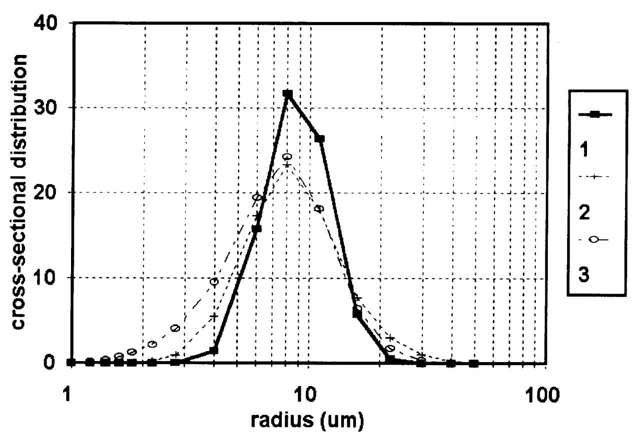

Figure 2. Inversion of the MWMFOV data set for the model size distribution. 1 - initial lognormal; 2 - inverted; 3 - inversion with input parameters disturbed by 3% random error.

Conclusion

Measurements with the MWMFOV photometer showed that the instrument is suitable for the investigations of the microstructure of semi-transparent clouds. Future plans are to modify the photometer in order to use it also for the measurements of the clear-sky spectral extinction.

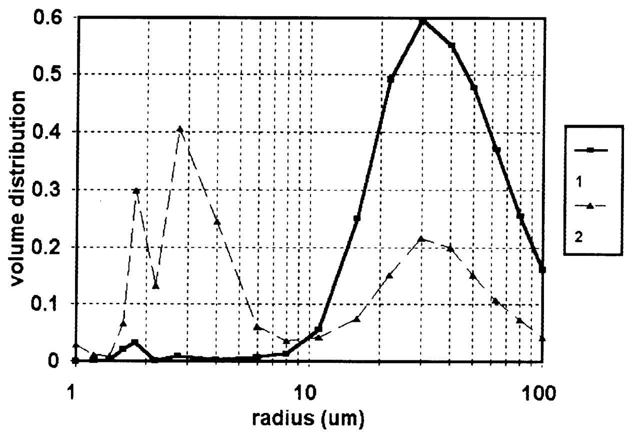

Figure 3. Volume size distributions retrieved from MWMFOV measurements at Zvenigorod. 1 - Ci, 28.07.97; 2 - Ci + Cu, 30.07.97.

Acknowledgments

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