Fluctuations of radiation from cloudy sky in the 3–5 and 8–13 μm spectral regions

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The spatial structure of radiance fluctuations in cumulus and stratocumulus has been studied simultaneously in the 3–5 and 8–13 μm spectral regions. Some data on correlation between fluctuations in both of these spectral regions are presented.

As known, radiation from clouds strongly varies in space and time. Its spatiotemporal structure can be studied only with fast-response scanning equipment having high sensitivity and high spatial resolution, supplied with automated data acquisition and processing systems.

In this paper we present some tentative results on fine spatial structure (up to several minutes of arc) of the radiation from cumulus (*Cu*) and stratocumulus (*Sc*) clouds derived from their images. Image frames had the size that measures, on the average, 60° of the azimuth angle α and from 10 to 20° of the zenith angle θ; the bias between successive frames in θ was from 1 to 8°; the number of realizations (the number of rows in an image frame) was from 3 to 21. A realization was digitized in an angular step of 7 to 10 minutes of arc. The least number of quanta (elements) N in a realization always was in excess of 300. The mean values and variances of the fluctuations were determined using 5 to 7 readouts. The dependence of mean values (over the zenith angle) in the region of 3 to 5 μm can be approximated by a linear function as the zenith angle ranges from 50 to 80°.

The mean value is $\approx 4 \cdot 10^{-5}$ W·cm^{-2}·sr^{-1} at θ = 60° for *Cu* (cloud fraction of 4 to 6), what is practically equal to that of the black body. In the region of 8 to 13 μm it is $\approx 3 \cdot 10^{-3}$ W·cm^{-2}·sr^{-1}.

The variances, σ^2, of fluctuations varied widely depending on θ. In both of the spectral regions the variance behaves similarly. However, the variance for *Cu* in the region of 3 to 5 μm drop somewhat more slowly than in the region of 8 to 13 μm. It was found that the variance of fluctuations in the 3–5 μm region for *Cu* at the cloud fraction of 4 to 6 and the angle $\theta \approx 75°$ can achieve $\approx 10^{-10}$ (W·cm^{-2}·sr^{-1})^2 and even larger, what is likely to be caused by the contribution from reflected solar radiation. Such a behavior of the fluctuation variance has been found for stratocumulus and thick cumulus clouds as well. Spatial spectra of cloud radiance fluctuations in the 3–5 μm region can be approximated, as in Refs. 1 and 2, by the expression

$$G(\omega) = \sigma^2(\omega)\ 1/\omega^{S(\theta)},$$

where $S(\theta)$ is the function changing from 1.67 to 2.3 for the angles $\theta \approx 75$ and 40°, respectively; $\sigma^2(\omega)$ is the variance of the radiance fluctuations at the spatial frequency ω.

Distributions of the fluctuation variance over spatial frequencies for different cloud shapes and cloud fractions in the 3–5 and 8–13 μm spectral regions are somewhat different in slope and magnitude. In some cases the difference between the values of $\sigma^2(\omega)$ may reach an order of magnitude.

Spatial correlation between the radiance fluctuations in the 3–5 and 8–13 μm regions strongly varies with the azimuth angle and taking values from 0.36 to 0.96 for the same realizations obtained simultaneously. As the angle (denoted as ψ) between the directions toward the Sun and the mean, over a realization angle, increases, the correlation coefficient increases, and vice versa. This fact can be explained by the influence of solar radiation reflected from clouds.

The ψ dependence of the correlation coefficients is given in the Table 1 for the cumulus and stratocumulus clouds (cloud fraction from 4 to 6) in the 3–5 and 8–13 μm regions.

Table 1.

Cloud type	Correlation coefficients					
	ψ°					
	30	50	70	90	120	> 120
Cu	0.39	0.61	0.74	0.83	0.89	0.94
Sc	0.36	0.56	0.68	0.74	0.81	0.86

The dependence of the correlation radii in the spectral regions studied is similar for *Cu* and *Sc*; their dependence on θ is similar to that reported in Ref. 2.

References

1. M.I. Allenov, *Methods and Instrumentation of Spectroradiometry of Natural Media* (Gidrometeoizdat, Moscow, 1992), 262 pp.
2. M.I. Allenov and V.A. Solov'ev, Trudy Ins. Exp. Meteorol., Issue 25 (160), 3–14 (1995).

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