Mean Fluxes of the Near-Infrared Radiation in Broken Clouds

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Radiation codes of current general circulation models (GCMs) involve calculations of the spectrally integrated upward and downward fluxes of solar and thermal radiation at different atmospheric levels. For the visible, vertical profiles of the mean fluxes of upward and downward radiation in cumulus are studied by Zuev et al. (this volume). The aim of this study is to investigate the vertical profiles of the mean spectral fluxes of infrared (IR) solar radiation and the absorption in the field of cumulus clouds. The model of the atmosphere and methods for calculating the mean spectral fluxes in the near-IR spectral range are discussed in detail by Titov et al. (1994).

Calculation Results

We let $R_{St}(z,\lambda)$ and $R_{Cu}(z,\lambda)$, $Q_{s,St}(z,\lambda)$ and $Q_{s,Cu}(z,\lambda)$, and $S_{St}(z,\lambda)$ and $S_{Cu}(z,\lambda)$ denote the mean spectral fluxes of upward, downward diffuse, and unscattered radiation at a height $z = const$, respectively; $P_{St}(\lambda)$ and $P_{Cu}(\lambda)$ denote spectral absorption by the layers of stratus and cumulus clouds, respectively.

The effects of the cloud field stochastic geometry on vertical profiles of the mean fluxes of visible radiation are discussed in detail by Titov (1987), Zuev and Titov (1994), and Zuev et al. (this volume). In the near-IR, the effects will be unchanged. However, to interpret calculation results, one must take into account the spectral dependence of the single scattering albedo and the absorption spectra of atmospheric gases. Water vapor and carbon dioxide possess strong absorption bands and therefore represent the most active absorbers in this spectral range. We treat the atmosphere in the altitude range 0-16 km. Ozone amount and, hence, absorption are maximum at higher altitudes, so absorption by the ozone is negligible.

Multiple scattering in clouds is a major determinant of the upward and downward flux values. With a nonreflecting underlying surface ($A_s = 0$) and with intensively absorbing water droplets and atmospheric gases, a considerable portion of radiation is absorbed within the cloud layer, and the diffuse radiation fluxes are very small (Figure 1). In the broken clouds, a considerable portion of the incident solar radiation propagates in cloud gaps (“holes”) and, without scattering, can reach the surface through the spectral intervals with weak gaseous absorption (transparency microwindows). For instance, for $\lambda > 2.9$ µm, $S(0,\lambda)$, the mean flux of direct radiation at the surface level, may be as large as ~0.1-0.4. We note that for $\xi_\otimes = 0°$, the mean fluxes of direct radiation in cumulus coincide with the corresponding fluxes in equivalent stratus, i.e., $S_{St}(0,\lambda) = S_{Cu}(0,\lambda)$. For the meaning of the expression “equivalent stratus clouds” see Zuev et al. (this volume).

For $A_s > 0$, direct radiation flux, reflected from the surface and reaching without scattering an altitude $z > H^b_{cl}$ (with H^b_{cl} the lower cloud boundary), will be essentially cloud-type dependent. Indeed, for stratus clouds partially covering the sky, the above radiation will again propagate in the cloud gaps (this time, in the upward direction). As a result, $R_{St}(z,\lambda)$ assumes large values in the transparency micro-windows (Figure 1b, curve 4), but the mean spectral absorption $P_{St}(\lambda)$ is practically unchanged with A_s (Figure 1c, curves 2 and 4).

The situation is quite the contrary with the field of cumulus clouds. The above mentioned radiation component will propagate in gaps between cumulus clouds, but the mean angle $\alpha = L/H^t_{cl}$ within which a gap is seen from the ground will be significantly smaller compared with that in the stratus cloud case. Here, L is the mean distance between

(a) Titov, G. A., T. B. Zhuravleva, and V. E. Zuev. 1994. Mean radiant fluxes in the near-IR spectral range: Algorithms for calculation. Submitted to *J. Geoph. Res.*

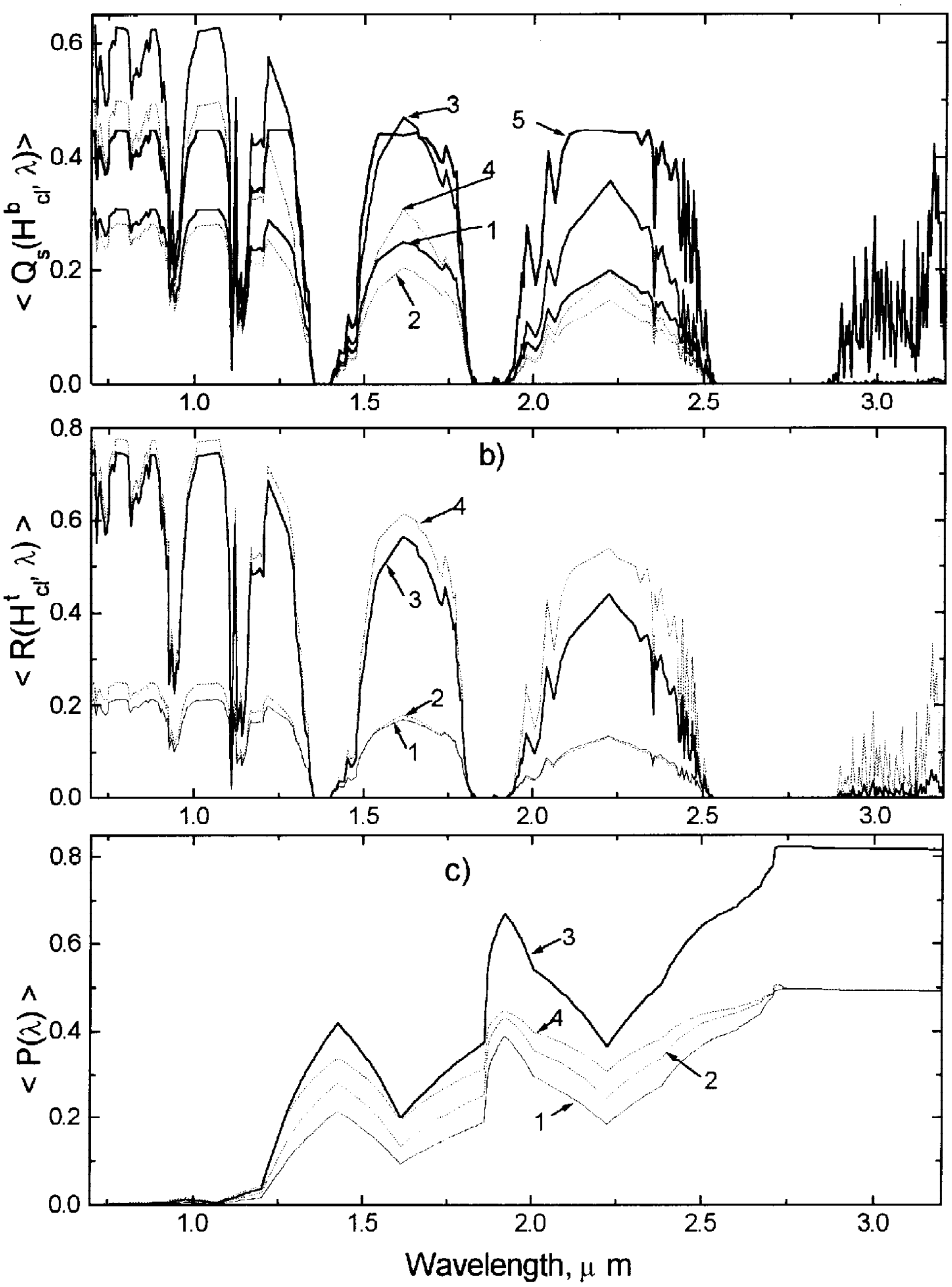

Figure 1. Mean fluxes of (a) downward radiation and (b) upward diffuse radiation as well as (c) absorption in the cloudy layer (by cloud droplets only, without the gaseous absorption). Computations with $\sigma_{\lambda=0.71\,\mu m}$ = 30 km^{-1}, $\xi_{\otimes}$ = 0°, N = 0.5, D = 0.25 km and for different surface albedoes: (1, 2) A_s = 0, (3,4) A_s = 0.8. Solid lines are for cumulus, dashed lines for stratus. Curve 5 in Figure 1a indicates mean flux of direct radiation at the surface level.

clouds, and H^t_{cl} is the height of the cloud upper boundary. Consequently, with the single scattering albedo small, a considerably larger portion of the above radiation component will be absorbed by cumulus clouds. In particular, for $\lambda > 2.9$ µm, $R_{Cu}(z,\lambda)$ will be practically unchanged (Figure 1b, curves 1 and 3), while $P_{Cu}(\lambda)$, the mean absorption in the cumulus cloud field, may be substantially increased (Figure 1c, curves 1 and 3).

Note that the spectral behavior of the upward radiation fluxes is consistent with the data of Wiscombe et al. (1984) obtained for their stratus cloud case.

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