# Internet-accessible database "Numerical radiation model of single-layer broken clouds"

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The peculiarity of theoretical studies of the atmospheric processes is that they imply manipulation of dissimilar data arrays (spectra of atmospheric gases, statistical models of height variation of the atmospheric parameters, spectra of radiation in the upper atmosphere, and so on). Internet access to such data has been arranged at the Institute of Atmospheric Optics SB RAS. The data on statistical models of the atmosphere and spectra of solar radiation from the Kitt Peak observatory and the data for calculation of the effective cloud fraction and solar radiative flux are accumulated at the "Models of atmosphere" site (http://model.iao.ru). The most recent data form the basis for the Internet-accessible version of the "Numerical radiation model of single-layer broken clouds (the visible and shortwave spectral ranges)" database. This database allows a user to estimate, in the first approximation, errors arising in calculation of the solar radiative flux with neglect of horizontal inhomogeneity typical of real cloud fields.

The study of physical regularities determining large-scale dynamics and power processes in the atmosphere requires, whenever possible, accounts for the mechanism of radiation interaction with clouds, which is the main regulator of the radiant heat exchange. This necessitates development of new simplified techniques for calculation of radiative fluxes in the shortwave and longwave spectral regions. On the one hand, these techniques should describe the radiative transfer in the actual atmosphere as accurately as possible and, on the other hand, they should be rather efficient from the viewpoint of the computer resources available.

A new approach to parameterization of shortwave radiation fluxes in single-layer broken clouds was proposed in Ref. 1. This approach accounts for the effect of stochastic geometry of actual cloud fields and does not imply computations more cumbersome as compared to the horizontally homogeneous cloud model. This approach consists in the following.

Traditionally, solar fluxes under broken cloud conditions $F_{\mathrm{bc}}$ were calculated based on the radiative transfer equation with the deterministic optical characteristics and represented in the form

$$F_{\mathrm{bc}}(z) = N\, F_{\mathrm{pp}}(z) + (1 - N)\, F_{\mathrm{clr}}(z), \qquad (1)$$

where the subscripts "pp" and "clr" stand for radiative fluxes under the overcast and clear sky conditions, respectively; $N$ is the cloud fraction. This approach provides adequate results only for stratus-type clouds, for which the aspect ratio $\gamma = H/D \ll 1$ ($H$ is the geometrical thickness of the cloud layer; $D$ is the characteristic horizontal cloud dimension) and considerable errors in calculation of radiative characteristics in cumulus ($\gamma \approx 1$). In Ref. 1 for computation of spectral mean (integral) fluxes of the upward and downward going solar radiation in broken clouds at the level $z$ it was proposed to use the representation similar to Eq. (1) but with the effective cloud fraction $N_{\mathrm{e}}$ substituted for the cloud fraction:

$$F_{\mathrm{bc}}(z) = N_{\mathrm{e}}(z)\, F_{\mathrm{pp}}(z) + [1 - N_{\mathrm{e}}(z)]\, F_{\mathrm{clr}}(z). \qquad (2)$$

This allowed the effects caused by both the finite horizontal cloud dimensions and the random cloud geometry to be taken into account. Since $F_{\mathrm{pp}}(z)$ and $F_{\mathrm{clr}}(z)$ can be calculated based on effective radiation codes developed within the framework of the horizontally homogeneous cloud model, the problem of calculation of the mean fluxes can be reduced to seeking a quick and convenient method for calculation of $N_{\mathrm{e}}(z)$.

In Ref. 1 we drew the following conclusions:

(a) in the visible spectral region (0.4–0.7 μm) one can neglect the dependence of the effective cloud fraction on $z$: $N_{\mathrm{e}}^{\mathrm{vis}}(z) = N_{\mathrm{e}}^{\mathrm{vis}}$;

(b) the main parameters determining variations of $N_{\mathrm{e}}^{\mathrm{vis}}$ are the following five parameters: cloud optical thickness $\tau$, cloud fraction $N$, aspect ratio $\gamma = H/D$, solar zenith angle $\xi$ , and surface albedo $A_{\mathrm{s}}$;

(c) in a wide range of input parameters (see below), the relation between the effective cloud fraction in the visible region $N_{\mathrm{e}}^{\mathrm{vis}}$ ($\lambda = 0.69$ μm) and in the spectrally integral (0.4–3.6 μm) region $N_{\mathrm{e}}^{\mathrm{sw}}$ is well described by the following functions:

in the subcloud atmosphere $0 \le z \le Hb_{\mathrm{cld}}$, $Hb_{\mathrm{cld}}$ is the cloud bottom:

$$N_{\mathrm{e}}^{\mathrm{sw}}(z) = N_{\mathrm{e}}^{\mathrm{vis}}(1.06 - 0.06 \cdot N_{\mathrm{e}}^{\mathrm{vis}}), \qquad (3a)$$

in the cloud-topped atmosphere $Ht_{\mathrm{cld}} \le z \le Ht_{\mathrm{atm}}$, $Ht_{\mathrm{cld}}$ and $Ht_{\mathrm{atm}}$ are cloud and atmospheric tops, respectively:

$$N_{\mathrm{e}}^{\mathrm{sw}}(z) = N_{\mathrm{e}}^{\mathrm{vis}}(0.98 + 0.02 \cdot N_{\mathrm{e}}^{\mathrm{vis}}). \qquad (3b)$$

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It is important to note that Eqs. (3) were obtained for liquid-droplet clouds, which occupy the 1.0–1.5 km layer. However, as computations show, they remain valid as the cloud bottom moves up to $Hb_{\rm cld} = 5$ km, that is, almost for the entire set of $Hb_{\rm cld}$ values typical of low- and middle-layer liquid-droplet clouds.[2]

Thus, if we know the shortwave radiation fluxes $F^{\rm sw}_{\rm pp}(z)$ and $F^{\rm sw}_{\rm clr}(z)$ calculated within a horizontally homogenous cloud model with some radiation code, as well as $N^{\rm vis}_{\rm e}$, then using Eqs. (2) and (3) we can quickly compute the shortwave flux under conditions of stochastic broken clouds. Since there are no fast and accurate methods for calculation of the effective cloud fraction in the visible region, in Ref. 1 it was proposed to construct a numerical model for estimating $N^{\rm vis}_{\rm e}$. This model uses the fluxes of upward and downward going radiation ($\lambda = 0.69$ μm) calculated by Eq. (2) at different atmospheric layers $z = 0$, 0.5, 1.0, 1.5, 3.0, 5.0, 7.0, 9.0, 10.0, 12.0, 14.0, and 16.0 km (cloud layer in the height range of 1–1.5 km) for the following values of input parameters:

– cloud fraction $N = 0.0, 0.1, 0.3, 0.5, 0.7, 0.9, 1.0$;
– aspect ratio $\gamma = 0.0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, 2.0$;
– solar zenith angle $\xi = 0, 20, 40, 60, 80°$;
– cloud optical thickness $\tau = 5, 10, 15, 20, 40, 60$;
– surface albedo $A_{\rm s} = 0.0, 0.3, 0.6, 0.9$.

The steps for each of the parameters were chosen so that the error of linear interpolation of $N^{\rm vis}_{\rm e}$ for intermediate values of $N$, $\gamma$, $\xi$, $\tau$, and $A_{\rm s}$ did not exceed the relative error of $N^{\rm vis}_{\rm e}$ calculated by Eq. (2), which was within 2–3% in most cases.

For fast access and free use of the obtained data, they are planned to be accessible through the Internet.[3] The "Models of the atmosphere" (http://model.iao.ru) site accumulates the data on statistical atmospheric models[4–6] and solar radiation spectra obtained at the Kitt Peak Observatory,[7] as well as the data for calculation of the effective cloud fraction and solar radiation fluxes. The most recent data were put in the basis of the first bilingual (Russian and English) version of the Internet-accessible "Numerical radiation model of single-layer broken clouds (visible and shortwave spectral regions)" database at http://model.iao.ru. Two modes of operation with this database are realized by now.

The first one is "The effective cloud fraction" that provides an access to the values of the effective cloud fraction in the visible spectral region calculated for the above range of the input parameters: $N^{\rm vis}_{\rm e} = N^{\rm vis}_{\rm e}(N, \gamma, \xi, \tau, A_{\rm s})$. For a convenient presentation, $N^{\rm vis}_{\rm e}$ is considered as a function of two variables, the other three parameters being fixed. Thus, for example, to estimate $N^{\rm vis}_{\rm e}$ variations at varying $N$ and $\xi$, the user should, first, select the other three parameters $\gamma$, $\tau$, $A_{\rm s}$ from the list, fix their values $\gamma = \gamma^*$, $\tau = \tau^*$, $A_{\rm s} = A^*_{\rm s}$, and then specify the intervals of variation and the steps for the two variables selected $N$ and $\xi$. As a result, the user obtains a table of $N^{\rm vis}_{\rm e}$ values in the specified range of the input parameters.

The second mode is "The solar radiation fluxes" that serves to display the earlier calculated fluxes of the upward and downward going solar radiation ($\lambda = 0.69$ μm) in the cloudless atmosphere and in the atmosphere with a layer of continuous or broken clouds in the height range of 1–1.5 km. Once the atmospheric conditions (clear, overcast, broken clouds) and input parameters are selected from the corresponding lists, the user obtains a table with the mean values of upward and downward going fluxes of radiation (nonscattered, diffuse, and net) at different atmospheric layers. The radiative fluxes are calculated assuming a unit unidirectional solar radiation flux to be incident on the atmospheric top.

The database described was developed in MySQL DBMS and is a set of tables. The table with the values of the effective cloud fraction is nothing else than tabular specification of the function of five arguments, that is, five columns of the table contain "nodal" values of the input parameters, and the sixth column contains the values of the function at these points. The rest tables contain the values of the upward and downward going solar radiation fluxes calculated earlier. The data are separated into different tables according to atmospheric conditions (clear, overcast, broken clouds) and input parameters, at which they were calculated. With the use of SQL queries, the database was filled with the existing calculated data on the effective cloud fraction and solar radiation fluxes.

In the "Effective cloud fraction" mode the user can specify arbitrarily (not coinciding with the nodal ones) values of the input parameters. The effective cloud fraction at intermediate values of $N$, $\gamma$, $\xi$, $\tau$, and $A_{\rm s}$ are calculated through successive linear interpolation of $N^{\rm vis}_{\rm e}$ at the nodal points. Interpolation is made by a function written in PHP. SQL DB queries are used to retrieve the nodal values of the effective cloud fraction closest to the input values of the parameters. Since the number of SQL queries can be rather large, some optimization was made in the system organization.

The optimization consists in the following. The step specified by the user for one of the five parameters determining $N^{\rm vis}_{\rm e}$ can often be much smaller than the step between the calculated nodes. This means that two or more values of this parameter fall within the same interval of the computational grid and, consequently, interpolation should be performed without the corresponding DB queries, using the values obtained at the previous step.

The data contained in the DB and obtained in calculations are visualized as HTML documents. The system interactivity is provided by PHP and JavaScript scripts for dynamic page generation with the use of CGI technologies. Operation with the DB is performed through dialog forms being tables with control elements: input fields or lists, prompts explaining every field, and buttons to proceed or clear the information entered.

In addition to the values of the effective cloud fraction and visible radiation fluxes, the site includes a brief description of the approach proposed, the statistical atmospheric model, within which the calculations were performed, and detailed instructions for the user. The data available at this site are interesting for specialists in geophysics, atmospheric physics, and mathematical simulation of mesoscale atmospheric processes.

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