Actinometrical features of basic cloud types

Sergey V Zuev, Nikolay P Krasnenko, and Elena S Kartashova

Institute of Monitoring of Climatic and Ecological Systems SB RAS, 10/3, Akademichesky pr., Tomsk 634055, Russia

E-mail: zuev@imces.ru

Abstract. In this paper, the authors propose a method for determining the main forms of clouds using an analysis of the diurnal variation of direct and diffuse solar radiation. This approach allows operating the process of determining the sky state automatically, which in most cases requires the presence of an observer at the point of measurement. For this purpose, the authors use the direct radiation transmission ratio and diffuse radiation changes with respect to cloudless sky, which have specific values for various forms and types of clouds. The method can be especially effective in cases where measurement of the basic characteristics of radiation is carried out with automatized actinometrical complexes.

1. Introduction

Particular attention by the climate study of areas is required to pay to the mechanisms of interaction of cloud fields and solar radiation, because climate has a strong sensitivity to them [1]. Along with the direct objective of atmospheric optics, which allows counting the radiation balance values using given parameter of the atmosphere and the underlying surface, the solving of inverse problem of atmospheric optics is of great importance, it allows recovering the atmosphere parameter through instrumental measurements of radiation characteristics results.

Studies of the relationship of solar radiation and various forms of clouds begin from the middle of the last century. One of the pioneers of such research is the S.I. Sivkov [2]. Currently, researches of mutual influence cloudiness and solar radiation in different ranges (integral, infrared, visible, and ultraviolet) are conducted mainly within the creation and development of radiative transfer models belonging to any atmospheric general circulation model. In particular, such work is carried out in the A.M. Obukhov Institute of Atmospheric Physics RAS [3], in the V.E. Zuev Institute of Atmospheric Optics SB RAS [4], and in the NASA (USA) [5].

The processes of clouds formation are influenced by many factors, each of which generates its own specific, peculiar, typical only for the particular form of clouds, microphysical, genetic and morphological features. The phase composition of the clouds (water, crystalline or mixed) determines their microphysical peculiarities. Genetic features depend on the conditions occurrence, which are attributable to stratiform clouds, waveform or cumuliform clouds. The appearance and quantity, the cloud base height, the vertical and horizontal dimensions determine the morphological characteristics of clouds. All the typical and usual features of the clouds on their own and in combination with each other have different effects on the value of coming to the surface direct *S* and diffuse *D* radiation, by virtue of the fact that each form and type of clouds has its own specific, peculiar actinometrical features, which can be divided into amplitude and temporal. Amplitude features depend on the microstructure and morphology of clouds and demonstrate their ability to influence the direct and diffuse radiation values. Temporal features depend on the genetics and morphology of clouds and affect the change rate of min and max values of direct and diffuse radiation, through which we can judge the speed of movement of the clouds across the sky. Thus, knowing the value of direct and diffuse radiation, it can be determined what types of clouds are most likely presented in the sky at a given time.

2. The influence of the basic cloud types on the direct and diffuse radiation

Figures 1 and 2 show the examples of the diurnal variation of direct and diffuse radiation for June 10, 2014, when during the day the in sky predominantly cumulus clouds were observed, according to which it can be estimated that it has a significant impact on the value of S' and D compared with their values S'_0 and D_0 in the clear sky.

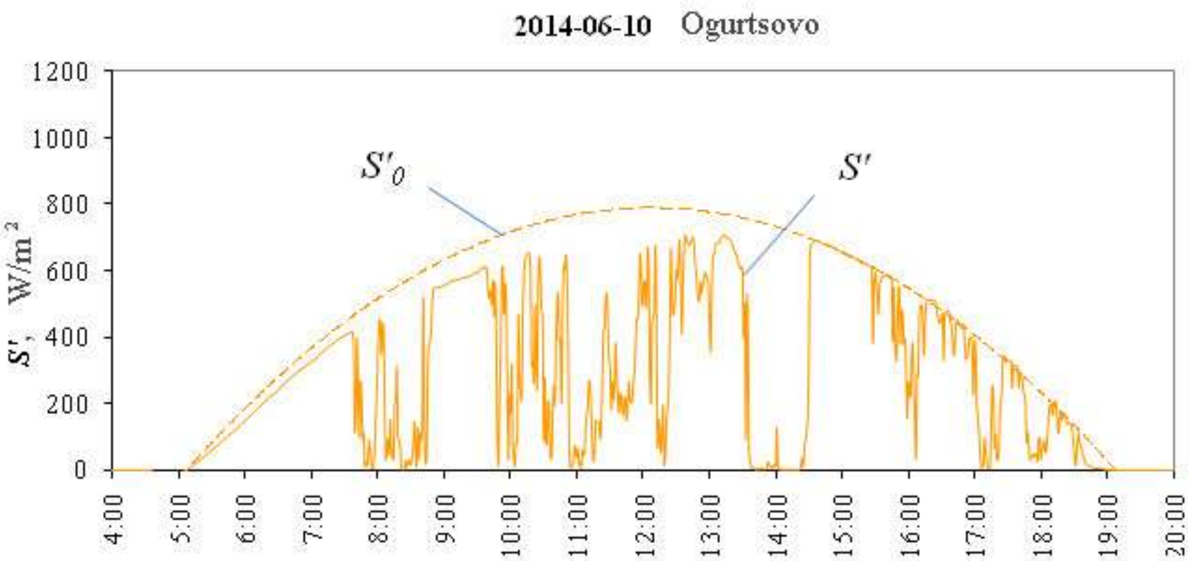

Figure 1. The influence of the cumuliform clouds on direct radiation.

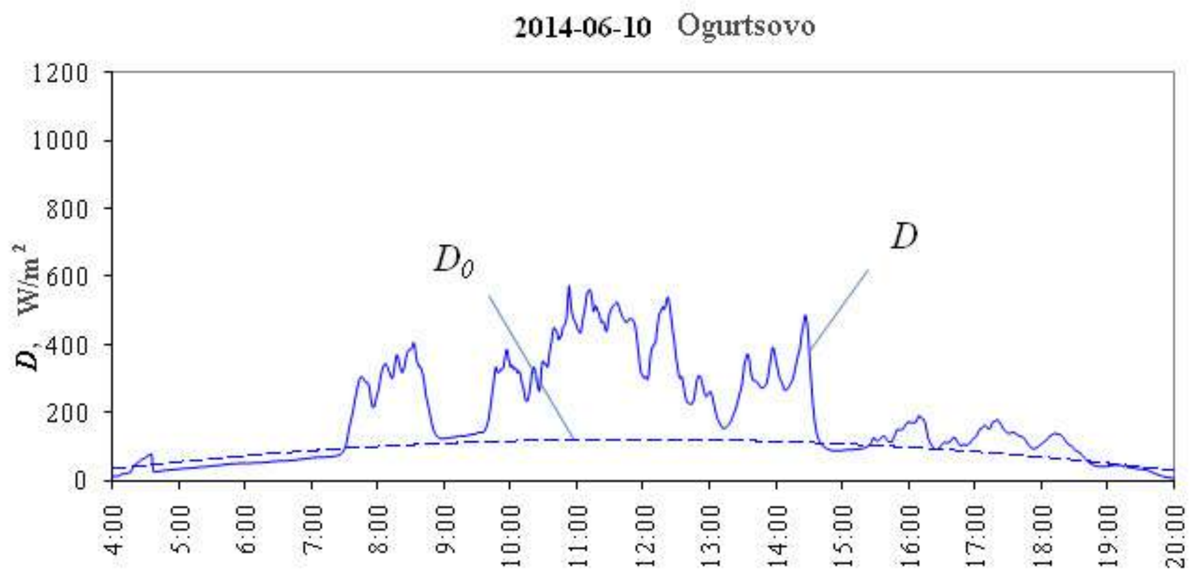

Figure 2. The influence of the cumuliform clouds on diffuse radiation.

Table 1 shows the typical and usual features of the basic cloud types, according to [6] in terms of their impact on the value of direct *S* and diffused *D* radiation (amplitude actinometrical features).

Table 1. The typical and usual features of the basic cloud types.

Clouds form	Decrease of direct radiation *S*			Change of diffuse radiation *D*			
				increase			
	weak	substantial	strong	weak	substantial	strong	decrease
Ci	x			x			
Cc	x			x			
Cs	x			x			
Ac		x			x		
As			x		x	x	
Ns			x				x
Sc			x		x		
St		x	x		x	x	
Cu			x		x	x	
Cb			x	x			x

It can be observed that more than in a half of cases, the basic cloud types have an unambiguous influence on the decrease of direct radiation *S* and change of diffuse radiation *D* (*Ci*, *Cc*, *Cs*, *Ac*, *Ns*, *Sc*). It gives an opportunity to parameterize them using amplitude actinometrical features simpler than *As*, *St*, *Cu* and *Cb*, for which it is necessary to introduce additional features, such as cloud amount and others.

3. Classification of clouds based on the transmission ratios of direct radiation and change of diffuse radiation

For analytical description of amplitude actinometrical features, the transmission ratio of direct radiation $C_S = S / S_0$ and change of diffuse radiation $C_D = D / D_0$ are used. Here *S* and *D* – measured values, and S_0 and D_0 – direct and diffuse radiation values by cloudless atmosphere at the same height of the Sun above the horizon.

Table 2. Ranges of values C_S и C_D for basic form, species and varieties of clouds.

	$0 \le C_D < 0.5$	$0.5 \le C_D < 1.6$	$1.6 \le C_D < 2.5$	$2.5 \le C_D \le 5$
$0 \le C_S < 0.5$	Cb_{med} *Ns*	*As neb., neb. pr.* *Sc op.* *St fr.* $\boldsymbol{Cu_{low}}$ $\boldsymbol{Cb_{hi}}$	*Ac* *As neb. op., und op.* *St* $\boldsymbol{Cu_{hi}}$ Cb_{low}	***Sc*** $\boldsymbol{Cu_{med}}$
$0.5 \le C_S < 0.8$		$\boldsymbol{Ci\ sp._{low}}$ $\boldsymbol{Ci\ fib._{hi}}$ *Ci ing.*	*Cs fib.* *Ac und., trans.,* ***Ac floc.*** $\boldsymbol{Ci\ sp._{hi}}$	*Cs neb.* *As*
$0.8 \le C_S \le 1.2$		*Ci* $\boldsymbol{Ci\ fib._{low}}$		

Cc

Table 2 shows the approximate ranges of values C_S and C_D for basic form, species and varieties of clouds (total 56 according to [6]). Indices *hi*, *med* and *low* indicate high (8-10), medium (4-7) and low (1-3) cloud amount respectively. Statistical data for pointed items are given below.

4. Results

Table 3 shows the statistical characteristics of ratios of C_S and C_D for some types of clouds, calculated according to the one-minute values of direct *S* and diffuse *D* radiation during July-August 2015 at the Sun's altitude $h \geq 30°$, obtained with the help of an automated actinometric complex of weather station "Ogurtsovo" (Novosibirsk) (WMO ID 29638), which is similar to the actinometric complex BSRN [7]. As S_0 and D_0 values, long-term average values of *S* and *D* were taken, when the sky is clear, according to [8].

Table 3. Statistical characteristics of C_S and C_D ratios.

Type and species of clouds	*N*	C_S				C_D			
		Min.	Ave.	Max.	σ	Min.	Ave.	Max.	σ
Cb_{hi}	245	0	0.01	0.46	0.04	0.41	1.58	4.49	0.70
Cu fr. *	28	*0.72*	*0.92*	*1.06*	*0.10*	1.16	1.62	2.43	0.34
Cu_{low}	11	0.01	0.33	0.49	0.17	0.97	1.37	2.06	0.39
Cu_{low} *	606	*0.55*	*1.02*	*1.11*	*0.07*	0.66	0.99	2.22	0.28
Cu_{med}	232	0	0.12	0.55	0.17	1.08	***1.94***	3.06	0.46
Cu_{med} *	409	*0.55*	*0.97*	*1.10*	*0.13*	1.00	***1.93***	3.55	0.48
Cu_{hi}	31	0	0.07	0.46	0.13	1.47	2.35	3.71	0.79
Sc	413	0	0.06	0.68	0.12	0.35	***2.02***	4.58	0.80
Sc *	11	*1.01*	*1.02*	*1.03*	*0.00*	2.07	2.14	2.34	0.08
Ac floc.	21	0.41	0.77	1.00	0.16	1.64	2.49	3.05	0.51
$Ci\ sp._{low}$ *	113	*0.58*	*0.99*	*1.08*	*0.12*	0.67	0.75	0.92	0.07
$Ci\ sp._{hi}$	9	0.18	0.32	0.51	0.12	2.34	2.45	2.61	0.10
$Ci\ sp._{hi}$ *	12	*0.55*	*0.77*	*0.99*	*0.15*	2.35	2.58	2.66	0.10
$Ci\ fib._{low}$ *	276	*0.83*	*1.02*	*1.07*	*0.05*	0.64	0.88	1.15	0.18
$Ci\ fib._{hi}$	69	0.07	0.40	0.55	0.11	1.11	1.86	2.33	0.28
$Ci\ fib._{hi}$ *	359	*0.55*	*0.81*	*1.05*	*0.13*	1.15	1.60	2.76	0.34

* - values by open Sun $\odot^2$.
N- measurements amount.

Form and cloud amount are determined according to the timed visual observations on this weather station (8 times a day) and to panoramic images of the whole sky, obtained at intervals of 2 minutes using the TV meter of cloud amount "Sineva" installed in the immediate vicinity of the actinometric complex and a integrated in the TV meter of cloud characteristics [9]. This cloud characteristics meter allows also determining the cloud base height, the speed and direction of the lower clouds drift. The exterior appearance of the meter and the image processing program interface are shown in Figure 3. Determination of cloud amount in this case is carried out using the RGB color model by finding of the sky blue areas free of clouds on color panoramic images. As an example, Figure 4 shows the values ranges of C_S and C_D ratios for cumulus and cumulonimbus clouds.

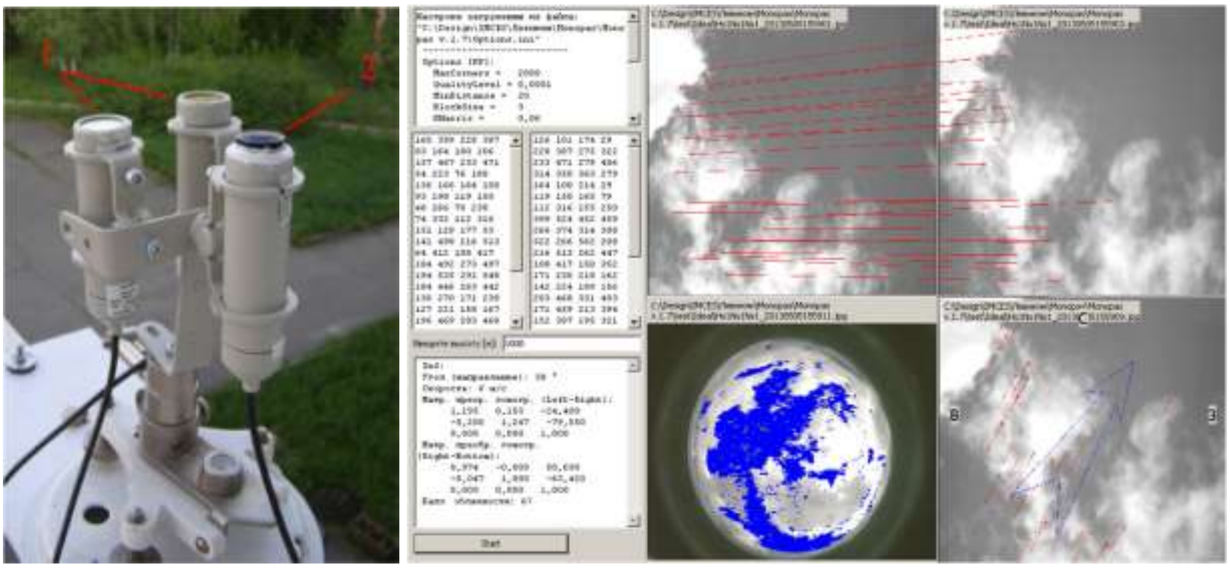

Figure 3. TV meter of cloud characteristics (1- ceilometer "Monopas", 2 – meter of cloud amount "Sineva") and image processing program interface.

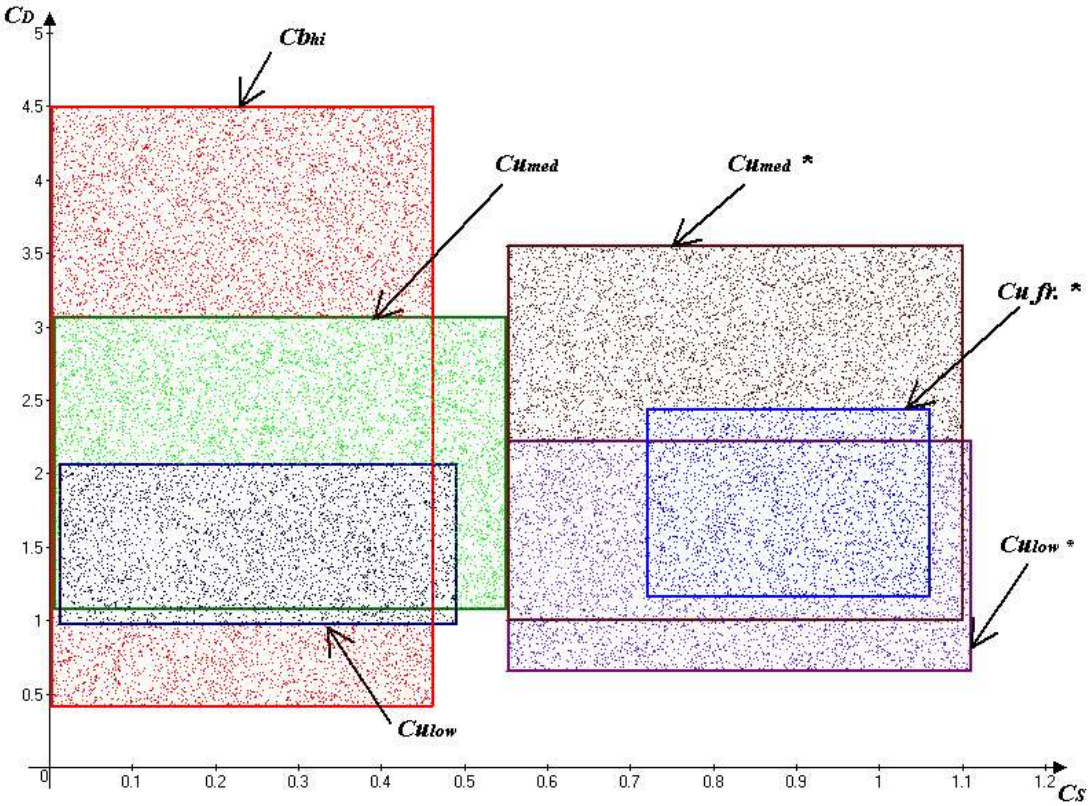

Figure 4. The value ranges of C_S and C_D ratios for cumulus and cumulonimbus clouds.

With the accumulation of data, change ranges of the C_S and C_D ratios for definite forms and types of clouds can be specified and corrected.

5. Conclusions

Different cloud types and species form their actinometrical features, which can be divided into amplitude and temporal. Cloud ability to influence the value of coming to the Earth surface direct and diffused radiation refers to amplitude features and depends on the microstructure and morphology of clouds. The change frequency of min and/or max values of direct and diffused radiation in certain short period of time in particular depends on the cloud genetics and refers to temporal features, by which we can judge the movement speed of clouds and their fragments in the sky. The use of these features allows parameterizing the basic cloud types and species and automatizing the process of estimation of sky condition for single-layered clouds.

Proposed in this study method allows defining the basic cloud types and species by their amplitude actinometrical features using analysis of the diurnal variation of the direct and diffuse solar radiation. The basic cloud types and species are divided into 3 classes according to the degree of their influence on the direct radiation C_S transmission ratio, and into 4 classes according to the degree of their influence on the diffused radiation C_D change ratio, taking into account the solar disk condition (open or closed by clouds) and cloud amount (high 8-10, medium 4-7, low 1-3). Such classification was conducted by the comparison of *S* and *D* values obtained with the help of an automated actinometrical complex of weather station "Ogurtsovo" (Novosibirsk) (WMO ID 29638) in July-August 2015, by cloud form and amount determined according to the panoramic all-sky images obtained using the TV meter of cloud amount "Sineva" installed in the immediate vicinity of the complex.

As follows from the analysis, the range of ratio values for C_S и C_D for cumulus clouds *Cu*, cumulonimbus clouds *Cb*, altocumulus floccus clouds *Ac floc*., as well as for cirrus dense *Ci sp*. and cirrus fibrous clouds *Ci fib*. By different cloud amount and solar disk condition were defined.

It's worth to remark that the use of temporal actinometrical features in addition to the amplitude ones allows more precise classifying the cloud on the ground of actinometrical information analysis.

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