STATISTICAL CHARACTERISTICS OF MORPHOMETRIC CLOUDINESS PARAMETERS IN DIFFERENT MESOSTRUCTURAL FORMATIONS

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Calculational results of morphometric cloudiness parameters, obtained by "Meteor"-satellite photograph photometry using a single-threshold recognition criterion, are presented. Statistical characteristics of the cloudiness parameters are discussed.

The characteristics that describe the spatial structure of cloudiness elements are of the greatest importance in a climatic model of cloudiness. Knowledge of their values is essential both in modeling radiation transfer processes and in the investigation of the natural resources of the earth.

In the present work the morphometric parameters of cloudiness of different mesostructure types in different seasons were calculated from cloud-field photographs taken in the visible range of the electromagnetic spectrum from satellites of the "Meteor" monitoring system. Realizations of the conventional brightness of the cloud fields were obtained with the help of a photorecording complex consisting of an S-4500 r-device and an SM-4 computer. The image of a selected fragment was read line-by-line and was recorded on the SM-4 magnetic tape drive in a format suitable for the ES-1033 computer. The raster dimension was equal to 50 μm and the number of elements was 512×400. Taking into account the scale of the photograph, the technique made it possible to obtain conventional brightness realizations with 512 pixels per line and an interpixel distance of 0.6 km. The distance between lines was also 0.6 km. However, statistical characteristics were calculated only for sections occurring every 12 km (every twenty lines).

Input/output quality .was monitored by both video display and photographic hard copy.

Several criteria (one-threshold, two-threshold and experimental) were applied to identify the cloudiness on the basis of the obtained realizations.

The one-and two-threshold criteria are based on an automated analysis of the brightness histogram of the image along the section (line). In the first case, when cloudiness with clear spaces was considered, the threshold value was taken to be equal to the value of the brightness at the first minimum after the first mode on the brightness histogram. Since only fragments with a dark underlying surface (land or sea) were chosen, the first histogram maximum corresponded to the values of the brightness of the underlying surface, while the others corresponded to those of cloudiness.

The two-threshold criterion provides a more detailed distinction of cloudiness. As in the one-threshold case, the first threshold is determined now automatically on the basis of the first minimum after the first histogram maximum. It distinguishes "black" clear spaces from "grey" and "white" clouds. The second threshold is selected automatically on the basis of the last minimum before the last maximum on the histogram and distinguishes the "grey" clouds from the "white" ones.

The experimental threshold criterion was applied in complicated cases. In this case the "greyest" region of the underlying surface or the darkest "grey" cloudiness in this fragment was defined on the initial photographs and on the SM-4 display screen. This region was marked, and the brightness values ever the 10 pixed × 10 pixed region were obtained, from which a mean brightness value was derived, which was taken as the threshold value. However, this method has low operational potential.

In the present work the one-threshold criterion was applied most commonly. In order to define the threshold value more precisely, a correction of the threshold was carried out with the help of the largest correlation coefficient between the initial line of the image and the restored one. With the optimal choice of the threshold the correlation coefficient amounted to 0.80 in most cases and the fiducial probability was not less than 95%. The restored line was then formed in the following way. The brightness values larger than the threshold were picked out from the initial line, in which case the scanning was now assumed to cover the cloudy region, and a brightness value of 200 was assigned to each point of the region. Brightness values lower than the threshold corresponded to the dark underlying surface, and the brightness value at each point of such a fragment was set equal to 20. In this way the restored line was formed, taking into account the distribution of cloudy and cloudless fragments. The correlation between the initial line (which was read from the image) and the restored one permits one to estimate the quality of the threshold. By sectioning the cloud field at angles of 45°, 90°, and 135° with respect to the latitude section, it is possible to investigate the anisotropy of the cloudiness and, along with the above-enumerated characteristics, to examine a number of mophometric parameters such as the mean length and mean width of the clouds banks, the distances between them, and the mean diameter of the clouds cells. The statistical characteristics of the cloudiness parameters, such as the moments, the distributional density, and the spatial correlation function and the spatial spectrum of the brightness fluctuations, were calculated on an ES-1033 computer.

The mean sizes of the cloudy regions in the fields of the closed cells of strato-cumulus had a smaller values, amounting to 5-12 km, sometimes as high as 19 km. The sizes of the clear spaces in such regions were nearly half those in the fields of Intense cumulus.

A number of investigations have been made of the spatial structures of cloudiness micro- and mesoscales from both airborne and satellite platforms[1–6]. The two methods are complement each other, but improvements in the resolution of the satellite equipment to a few tens of meters or less make it possible in most cases to do without the airborne data. The satellite technique has a great advantage in global investigations of cloudiness, especially in almost inaccessible regions. Analysis of the calculated results obtained in the present work by the one-threshold criterion shows that the mean sizes, the rms deviation of the sizes of the cloudy and cloudless regions, and the cloudiness concentration all strongly depend on the type of mesostructure type. It should be noted that by the size of the cloudy (or cloudless) region we mean the section length of the cloud (or clear space) along the sounding path, i.e. it may be a chord, a diameter, or the major or minor axis of the elliptically-shaped projections of the clouds. Thus, one may speak only of a "conventional" cloud diameter. According to Ref. 3 the mean chord is 20% of the mean cloud diameter. It was found that the cumulo-nimbus in the larger cloudiness clusters have the largest mean sizes of their cloudy regions d = 20 km, and in wide cloud banks d = 26 km. The clear spaces (cloudless regions) in such cloud fields were large, too, and their mean sizes ranged from 17 to 40 km. Commonly their sizes were a little larger than those of the cloudy regions.

In cloudiness mesostructural formations such as narrow chains, open cells, grains, and cumulus domes the mean sizes of the clouds were rather smaller than in the adove mesostructure types. Thus, in one of the fields of cumulus chains the mean conventional diameter was 4 km and the mean size of the clear spaces was 31 km. Most commonly the clouds had sizes ranging from 0.6 to 5 km (in 82% of all cases), while the sizes of the clear spaces ranged from 0.6 to 18 km in 58% of cases. Moreover, clouds of such sizes covered only 4% of the (section).

In such types of mesostructural formations as chains, grains, and narrow banks of cumulus the cloud concentration increases as the cloudiness force increases. In cloudiness with a predominance of closed cells of clusters of cumulus the cloud concentration rises slowly as the cloudiness amount increases up to force 5–6. After this the concentration decreases as the cloud amount continues to increase.

TABLE 1.

Characteristics of some morphometric parameters of cloudiness in different mesostructural formations

	Meso structure type	region season	number of clouds	concentration of clouds, N 1000	force of cloudiness (numerator), clear space denoinator)	dimension (km) of cloudy regions (numerator) and clear spaces (denominator)				modal dimension of cloudy regions (numerator) and clear spaces (denominator), km	probability %
						min	max	mean	root-mean-square deviation		
1	Regular closed chains cells of strato-cumulus	Pasifi ocean, subtropics, S.H., summer	375	61.0	7.0/3.0	0.6/0.6	157.8/43.2	11.5/4.9	18.3/7.0	0.6 - 16.0/0.6 - 5.0	76/69
2	Open cells, chains and grains of cumulus	Pasifi ocean, subtropics, summer	271	44.1	2.2/7.8	0.6/0.6	30.0/148.8	5.0/19.7	5.1/20.4	0.6 - 3.5/0.6 - 15.0	48/61
3	chains and grains of cumulus ,a few cumulonimbus	Indian ocean, tropic winter	108	17.6/20.5	0.5/9.5	0.6/0.6	16.2/240.6	2.6/45.6	2.1/56.2	0.6 - 2.0/0.6 - 25.0	56/54
4	Banks of strong cumulus and cumuliform, packs of cumuliforms separate grains	Pasifi ocean, subtropics, summer	117	19.0/18.9	6.8/3.2	0.6/0.6	213.6/88.2	35.5/17.1	41.4/19.8	—	—
5	Disordered packs of cumuliforms separate domes in the cloudiness inside the topical convergency row.	Indian ocean, tropic spring	96	15.6/18.7	2.5/7.5	0.6/0.6	104.4/205.2	16.0/40.0	20.4/52.5	0.6 - 11.0/0.6 - 21.0	62/55

The characteristics of some cloudiness fields are presented by way of an example in Table 1.

The mean sizes of the cloudy regions on the basis of 20 sections of cloud fields of different mesostructure types as a function of cloud amount are shown in Fig. 1.

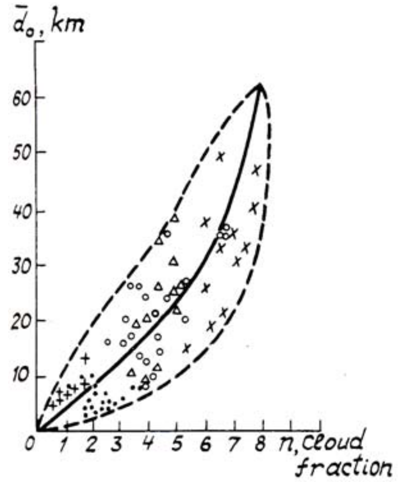

FIG. 1. Interdependence of cloud amount and mean sizes of cloudy regions
• – Cloudy massive N5. × – Cloudy massive N6.
+ – Cloudy massive N4. ○ – -Cloudy massive N21.
△ – Cloudy massive N20.

The sizes of the cloudy elements beyond force 5–6 increases sharply as the cloud amount increases. That is, for the large-sized clouds increase in their diameters makes the main contribution to their covering of the sky. But for the small clouds the cloud concentration plays a large part in the increase of covering. This conclusion is confirmed in Ref. 3.

With regard to the correlation between cloudiness size and the size of the clear spaces, one may distinguish three classes of cloudiness with different mesostructures. Such cloudiness types as the small clouds banks, chains, grains, domes, and open cells compose the first class. The comparatively small cloudy regions are separated here by big clear spaces. In this class the size range of the clear spaces is much more extensive than the size range of the cloud fields. In the second class, which includes the large-sized wide banks and the aggregations of cumulo-nimbus, the sizes of the cloudy regions are a little less than those of the clear spaces. In the third class consisting of the closed cells of strato-cumulus and the fragments of cloudiness macrobands the sizes of the cloudy regions exceed by far the sizes of the clear spaces. In this case a direct linear dependence of the size of the clear spaces on cloud size is observed. The distribution of both the cloudiness sizes and the clear space sizes in the different types of mesostructural formations are close to an *i*-distribution (it corresponds to the γ-distribution with coefficient of variation greater than 1). That is, small clouds and small clear spaces are the most commonly encountered forms in the clouds-fields sections (Figs. 2 and 3).

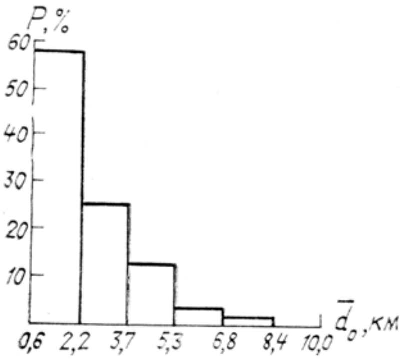

FIG. 2. Distribution of the mean sizes of cloudy regions.

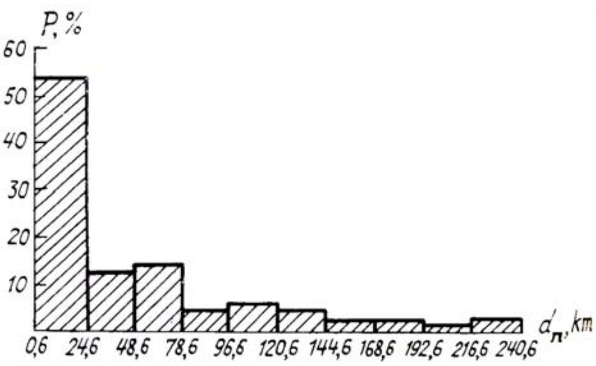

FIG. 3. The distribution of the mean sizes of clear spaces.

In conclusion it should be noted that the results obtained by the automated processing of the cloud-field photographs obtained by satellite are in agreement with the data that were obtained by other methods and are useful for investigations of the cloudiness of different mesostructural formations.

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