PROCEDURE FOR PROCESSING SATELLITE PHOTOGRAPHS FOR THE ESTIMATION OF MORPHOMETRIC CLOUDINESS PARAMETERS

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Received January 27, 1989

A procedure for processing photographs of clouds using automatically selected and corrected threshold criteria is presented. The use of a single-threshold criterion is shown to provide satisfactory recognition and reconstruction of clouds over the ocean.

The classification of clouds is one of the more difficult problems in the satellite climatology.[1,2] There are different techniques and algorithms for identifying clouds.[1]

The techniques of bispectral analysis and clusterization based on the threshold or statistical criteria have found the most widespread use. As a whole, the available experience in the processing of cloud images shows that threshold techniques are preferable for satellite climatology. The algorithms based on these techniques are more suitable for calculations, but there is a problem in the choice of good thresholds. The main difficulty consists of the fact that there is a large variation in the reflected and infrared radiation for different types of landscape under different weather conditions. This fact has a strong influence on the choice of threshold. A review of publications on the subject of determining different criteria for the identification of clouds is given in Ref. 1. It should be noted that together with the optimal choice of the criterion the possibility of identifying clouds and defining their characteristics also depends on the spatial resolution of the instrumentation, the viewing geometry, and the sensitivity threshold of the sensors. Among these factors the resolution of the equipment is the most important because it is impossible to distinguish small clouds and gaps with low resolution.

As our starting material we have chosen photographs of clouds from the satellites of the "Meteor" series in the visible range. The resolution of the photographs of the MSU-033 and MSU-050 apparatus is 1 and 0.25 km, respectively. Mainly ocean regions which provided a dark underlying surface were chosen in the photographs. The main stages of the work are presented below:

1. The dominant type of synoptic object is determined in the given region and during the given season from data on synoptic object repeatability.
2. For the dominant synoptic object the most typical generalized picture of clouds is determined by taking into consideration the stage of synoptic object development.
3. For typical cloud pictures the characteristic fragments with a definite type of cloudiness mesostructure are determined.
4. For chosen fragments of the generalized cloud field of a synoptic object the thresholds are determined and the statistical characteristics of the morphometric cloud parameters are calculated.
5. The statistical characteristics -of the cloud fragments for the dominant synoptic object are generalized.
6. From the generalized statistical characteristics of these fragments a statistical model of the morphometric parameters of the synoptic object cloud field is formed.

The morphometric characteristics that give an adequate description of a cloud field include the sizes of the clouds, the sizes of the gaps between the clouds and between the cloud banks, the length and width of the cloud banks and cloud bands, the diameter of a cloud cell, the width of the ring of a cell, the radius of curvature of the bands, the dimensions of meso-vortices, the cloud heights, the absolute ball of the clouds (gaps) or the cloud density, the concentration of clouds and gaps along a section of the path, the number of clouds and gaps, etc. These characteristics provide quantitative measures of cloud morphology and are connected with the specific thermodynamic conditions of the given synoptic object. Thus, the altitude of the cloud fringes of a cold front is closely connected with the wind velocity on the 500-mbar isobaric surface, and the length of a fringe depends on the specific humidity.[1]

We have used a number of methods to investigate the morphometric characteristics of clouds. In the initial stage of our work the sizes of the clouds, their number, and the number of gaps were evaluated by hand using various schemes. The images were then counted and digitized automatically, using a photorecording device consisting of a C-450 counter and an SM-4 computer. The image of the chosen fragment was read in line by line and recorded on magnetic tape by the SM-4 computer in the format of an EC-1033 computer with a raster step of 50 pm, the fragment format being 512×400. Recording quality was monitored with the help of a display and photodocumentation. The subsequent processing was carried out on the EC-1033 computer. Some part of the information was obtained by recording the image from satellite on tape with a high

0235-6880/90/01 047–3 $02.00

record density with subsequent transcription of the information to the magnetic tapes using the EC-1033 computer. Naturally, the large amount of data necessary for statistical processing can be obtained only by automatical technical equipment.

In the determination of the threshold value defining the cloud and non-cloud segments of the image, we have used various techniques to determine the cloud recognition criteria, namely, the single-threshold technique, the two-threshold technique, and an experimental technique.

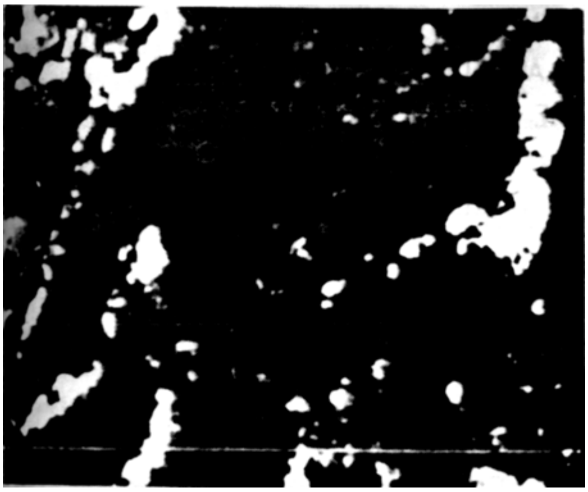

FIG. 1. The starting cloud field

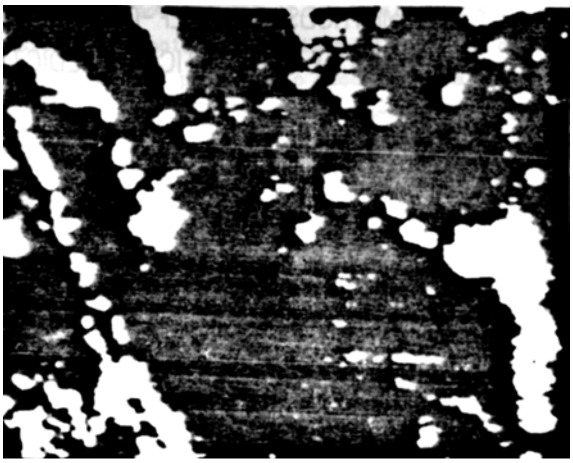

FIG. 2. The reconstructed cloud field

Single- and two-threshold criteria are based on an automatic analysis of the brightness histogram of the image along a profile. In the single-threshold criterion for cloudiness with gaps, as the threshold value we took the brightness corresponding to the first minima after the first mode in the brightness histogram. Since mainly dark underlying surfaces were chosen, the larger part, of which were ocean scenes, the first maximum in the histogram corresponds to the value of the brightness of the underlying surface, and the other maxima are for “grey” or bright ”white” cloudiness. as the brightness of the cloudy spots (”grey” and bright ”white” clouds) we took the brightnesses with values greater than threshold.

In order to more accurately specify the threshold value, we corrected it with the help of the largest coefficient of correlation between the initial and the reconstructed (with the threshold taken into account) image lines. In most cases the correlation coefficient was greater than 0.80 (confidence level not less than 9550 when the threshold was optimally chosen.

In complicated situations the brightness of the underlying surface alternates between ”black” and “grey” or there are observed along with the gaps to-some-degree transparent cirrus clouds over the more low-lying clouds. I.e., cirrus clouds over covered cells of stratocumulus. In these cases the single-threshold criterion, even when corrected, is not the optimal one, and it provides only rough recognition of the clouds, and exaggerates the sizes of the clouds and their number. The two-threshold criterion yields a finer cloudiness distinction. In this case the first threshold is determined automatically using the first minimum following the first maximum in the brightness histogram. The first threshold allows one to distinguish the “black” gap from the ”grey” and “white” clouds. The second threshold is chosen using the last minimum before the last maximum in the histogram, and it separates the “grey” from the ”white”. This case yields three realizations

a) a realization of the brightness of the gaps

$$B_{i\,black} < B_{1thresh};\; B_{i\,black} = 0,\; \text{if } B_i > B_{1thresh};$$

b) a realization of the brightness of the ”white” bright cloudiness

$$B_{i\,white} > B_{2thresh};\; B_{i\,white} = 0,\; \text{if } B_i < B_{2thresh};$$

c) a realization of the brightness of the ’grey” cloudiness

$$B_{1thresh} < B_i < B_{2thresh};\; B_{i\,grey} = 0,$$

$$\text{if } B_i < B_{1thresh},\; B_i > B_{2thresh}.$$

In what follows all of the statistical characteristics of the brightness are calculated for each of these realizations, and the morphometric parameters (the number of gaps, clouds, the mean size of the gaps, the clouds, the concentration of clouds, etc.) are determined.

The other method which we used consists of an empirical determination of the threshold. In this case we chose greyest section of the underlying surface or the darkest “grey” cloud in the fragment on the starting photograph and on the screen of the SM-4 computer display. The marker is brought to the fragment, and the brightness values of the section (with dimensions of 10×10 values) are chosen. Using them the mean brightness value was determined, which was taken to be the threshold value. This method was applied mainly to improve the accuracy of the results in difficult cases.

The reconstructed image is recorded in all cases on photographic film and compared with the starting one.

The starting and the reconstructed cloud fragments are shown in Figs. 1 and 2. It can be seen that the use of the single-threshold criterion for the case of cumulus clouds gives good results. The correlation coefficients between the starting and reconstructed lines varied from 0.88 to 0.97 (confidence level not less than 95%). Unsatisfactory results were obtained using this criterion for the case of stratocumulus cells covered by cirrus. Thus, the applied technique allows one to distinguish cloud formations reliably enough and to obtain their morphometric characteristics.

REFERENCES

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2. K.Yu. Kondrat'ev, *Satellite Climatology* (Gidrometeoizdat, Leningrad, 1983).