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TRACING THE DEVELOPMENT OF CLOUDS FROM GROUND-BASED VISIBLE IMAGES

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Abstract. *The subject of the present paper is detecting the variance of cloud optical thickness and visual assessment of the cloud spatial variability observed from earth surface during different meteorological conditions. The radiance of the cloud base, which is a measure for the cloud optical thickness, is read from ground-based visible images. The presence of very thin aerosol parcels surrounding the examined cloud in the scenes is an obstacle to determine the proper radiance of the cloud base because of the great amount of single scattered sunlight that is difficult to account for. Nevertheless, the interpretation of data from images of thicker clouds show that even time difference of several minutes between measurements may be indicative of the short time evolution of such type of clouds. The ground-based observations of clouds in appropriate time intervals may be used for short-term prediction of the weather.*

Introduction

Observations of clouds and retrieving their characteristics are of great significance for many scientific and applicative tasks. Clouds influence enormously the radiative budget and the climate of the Earth. They affect the data collected by remote sensing of the earth surface. The short-wave (or visible) flux is more sensitive than the IR (or long wave) flux to variability in the water content and base and top heights of observed clouds [1].

The main parameter that is related to the cloud-radiation interaction is the optical thickness. The brightness of clouds obsrvable from the earth surface decreases exponentially with their optical thickness, which is related to the water content of the clouds. The advantage of ground-based observations of clouds compared to satellite ones is in the great spatial and temporal resolution of the obtained data about changeability of the lowermost cloud layer. The subject of the present paper is detecting the variance of cloud optical thickness and visual assessment of the cloud spatial variability from images taken in appropriate time intervals during different meteorological conditions. The possibility of tracing the development of clouds using the variability of cloud brightness observed from earth surface is discussed.

The steady increasing of the cloud optical thickness is usually due to the processes of growth of the size and concentration of cloud droplets and could result in rainfall. It turns out that even time interval of several minutes between measurements may sometimes be indicative of the evolution of given type of clouds. Depending on the weather conditions, the decreasing of the cloud optical thickness may be related to the approaching dissipation of the thinner clouds or may be due to the growth of the water droplet size in dense clouds accompanied with the temporary decreasing of their concentration before beginning to rain [2]. The results show that after taking into account some considerations about the influence of cloud scattering, the variability of the area mean cloud optical thickness is representative of the cloud evolution because the observable changes are in agreement with the follow-up weather.

Data processing and interpretation

The main problem in ground-based observations is the need to take into account the effects of scattering and extinction of radiation by the atmosphere. The solar radiation scattered by the lower atmosphere and by the cloud is additive to the measured brightness of the cloud base. As far as the analyses presented here refer to series of images taken at practically constant atmospheric conditions (especially concerning the horizontal visibility), the influence of the atmosphere on the brightness of the cloud base is ignored. However, it is necessary to assure that the illumination from the sun and by the surrounding clouds must be alike for the series of images under consideration.

For calculating the brightness data, a weighted mean value is formed from the channels red, green and blue. The values of the brightness codes in the image are read by means of a software product specially created for the purpose. The camera specific settings such as shutter-speed time, aperture value and focus length are taken into account for converting of the digital image codes into values of brightness. As a consequence, dense clouds in an image may look brighter then thinner clouds in the next picture.

The following images in Figs. 1 to 4 were taken on 30.08.2006. The pressure P = 942.5 hPa is less than the normal for the month - a cyclone is oncoming. The first two pictures in Figs. 1 and 2 show the appearance of noon skies at about 12:30 p.m. in time interval of 130 seconds between the two frames. The clouds are scattered and the weather is still sunny. We would like to mention that the thinner clouds aloft give single scattered forward solar radiation, i.e. additional “noise” brightness to the measurement that is difficult to account for. The passing brightness of the upper part of these images increases. However, it could be noted that cloud bases raise up, and as result, the cooling of the clouds makes them stack in larger and thicker formations. The brightness of the cloud base at the lower part of images, as well as the mean area brightness decrease to over 3%. Current weather conditions set as a premise to become cloudy. The images of clouds in Figs. 3 and 4 are taken at 4:30 p.m. Actually, four hours later the brightness of clouds has diminished to 77.5%. Then the faster decrease (22.5% in time interval of 136 seconds) of the mean area brightness of clouds in Fig. 4 compared to that of Fig. 3 is related to the beginning of a drizzling rain.

Fig. 1 – 30/08/06

Fig. 2 – 30/08/06

Fig. 3 – 30/08/06

Fig. 4 – 30/08/06

Another illustration of cloud evolution manifested in consecutive visible images taken before a rainfall is presented in Figs. 5–8. On 19.01.2007 Bulgaria fell into the periphery of the cyclone Cyril that caused havoc to Western Europe. The pictures of clouds in Figs. 5, 6 are taken during fast lowering of the atmospheric pressure with 12 hPa in half an hour. All parts of the cloud, as well as the mean area brightness decreased by 5.8 % in time interval of only 73 seconds. The pictures of clouds in Figs. 7, 8 are taken 3 hours later showing the same region of the sky. The scattered clouds turned into thicker formations aloft. The skies are already mostly cloudy and much faster got darker – the linear average of the varying brightness decreased by 49 % in 220 secons. About two hours later it began to rain.

Fig. 5 – 19/01/07

Fig. 6 – 19/01/07

Fig.7 – 19/01/07

Fig. 8 – 19/01/07

Let us now trace the development of clouds in different weather conditions that went before a long period of clear cloudless skies. Images in Figs. 9–12 are taken on 01.09.2006 and are the outgrowth of the clouds formed during the cyclone of 30.08.2006 (shown in Figs. 1–4). The pressure is higher than the mean value for the season - 956,5 hPa. The first two pictures look at West from where wind of velocity 25 km/h is blowing. The trend of the clouds to become thinner is registered in less then 2 minutes. The following two pictures look at East showing the transform of the clouds that are changing sides in the sky. Clearly it can be seen that the clouds break apart becoming thinner and brighter.

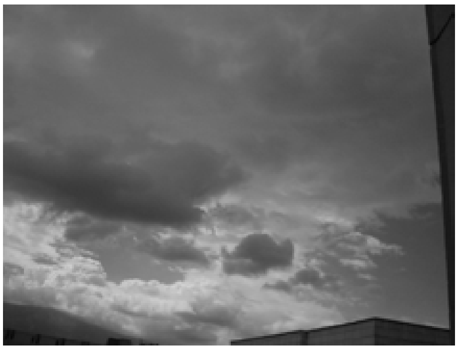

Fig. 9 – 01/09/06

Fig.10 – 01/09/06

Fig. 11 – 01/09/06

Fig. 12 - 01/09/06

Finally, in Figures 13–15 the development of clouds coming before a relatively short-term clearing up of the weather is shown. The trend of decreasing of the cloud optical thickness is clearly manifested for time interval of 50 minutes (first two images). The third picture is taken 4 minutes later than the second one. Now the trend is not quite evident because of the strong single scattered sunlight through the thinner parts of the cloud. It seems that the cloud becomes thicker. As was mentioned above, the presence of thin parcels of surrounding aerosol is an obstacle for the proper determination of the brightness of the clouds in images. Two hours later the sky almost cleared up and became sunny. Only the next day was cloudy again.

Fig.13 – 31/01/07

Fig.14 – 31/01/07

Fig.15 – 31/01/07

Results and conclusion

The possibility of tracing out the cloud evolution by estimates of cloud optical thickness from consecutive ground-based visible images is discussed. Some practical considerations concerning the necessary conditions for proper interpretation of the visual features of clouds are presented. The results show that the trend of the variance of cloud optical features is in line with the change of weather conditions. Ground-based optical observations of clouds are a useful technique for studying formation and development of small-scale clouds and may be used for short-term prediction of the weather.

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