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GROUND-BASED OBSERVATIONS OF CLOUD PROPERTIES IN RELATION WITH AEROSOL AND ATMOSPHERIC DYNAMICS

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Abstract: *Atmospheric processes determining the dynamics of aerosols are related to the radiation budget and the global climate of the Earth. The indirect effect of atmospheric aerosols on the radiation balance of the planet finds expression in their basic role in cloud formation, evolution and precipitation. The two decisive factors for droplet formation are the presence of sufficiently abundant particles and relatively large humidity of the air. Many other factors, such as aerosol size, chemical composition, and meteorological conditions, also influence the complex aerosol-cloud interactions.*

The objective of the present paper is to study the capacity of ground-based observations of clouds and their precursors by means of digital visible images of clouds under different meteorological conditions. The reversible transition aerosol-droplet-raindrop is considered with respect to the variability of the available meteorological parameters: relative humidity, horizontal visibility, temperature, pressure, wind speed, etc. The clouds as displayed in the visible images are characterized by their texture, shape, thickness, motion. These morphological features that are related to cloud microphysical properties may be indicative of the aerosol-cloud interactions. Our results show that the response of cloud appearance to the changes of meteorological conditions is practically immediate. We make use of the advances of ground-based observations to establish some relations between the variations of cloud physical properties and atmospheric parameters in very short time intervals. The detailed description of these relations for some types of clouds contributes to the knowledge of aerosol-cloud climatology.

Because of their high resolution in space and time, ground-based series of cloud photographs allow for quantitative and detailed analysis of cloud development in different meteorological regimes. Below in Fig. 1 three consecutive images of the sky in the south hemisphere over the city of Sofia taken within only 15 min are shown. They show clouds that are forming at the expense of the near ground aerosol. Half an hour earlier, the haze worsened the horizontal visibility (V) to 6 km that is below the ordinary value of 10 km. The newly created low clouds move up. The movement is evident from the position of clouds with respect to the sun. They join to the upper level low clouds that rose before, whose radiance slightly goes down, i.e. the upper clouds capture power from the clouds just formed from the surface aerosols and thus getting thicker. This is in accordance with the variations of the meteorological conditions - increasing of the relative humidity (RH) from 55% to 66%, and slight decrease of the pressure at the same time. The slight decreasing of the pressure serves as an impulse for the updraft of the aerosols serving as cloud condensation nuclei (CCN) of the lower clouds. The pumping effect during cloud formation is accompanied by improving visibility from 6 to 8 km. Because of the retaining values of high pressure P =1024 hPa at sea level >norm, the relatively high air humidity (RH > 60%) does not lead to the formation of clouds that give significant precipitation. Only the next day light rain showers occur. The abundance of larger in size surface aerosol below the clouds is not a sufficient condition for the growth of cloud droplets to raindrops at high pressure. A number of reversible interactions aerosol ↔ cloud keep the dynamical equilibrium that makes these clouds sustainable and long living.

The moist air (RH>60%) is a precondition for the observed cloud formation. The increasing of the relative humidity from 55% to 66% may be due to the wetter air carried by atmospheric advection (horizontal motion) during the intensification of the wind speed to 18 km/h. Another effect of the blowing wind is the accelerated evaporation of cloud droplets. But the additional water evaporation is probably due to the solar heating of the 3rd highest cloud layer. Actually, the veil around the solar disk through the highest cloud layer enlarges, that is it is getting thinner. The inference may be drawn that the effects of high clouds on low clouds pass through the changes of the atmospheric meteorological conditions. They prevent the heating of the surface and atmosphere and replenish water vapour supplies beneath. Thus they stipulate the formation of new low clouds. By now, only tentative result is known that low clouds do not exhibit obvious diurnal variations in presence of high clouds. To this point, the suggested mechanism of interactions may be a possible answer to the rhetorical questions found in climatologic studies.

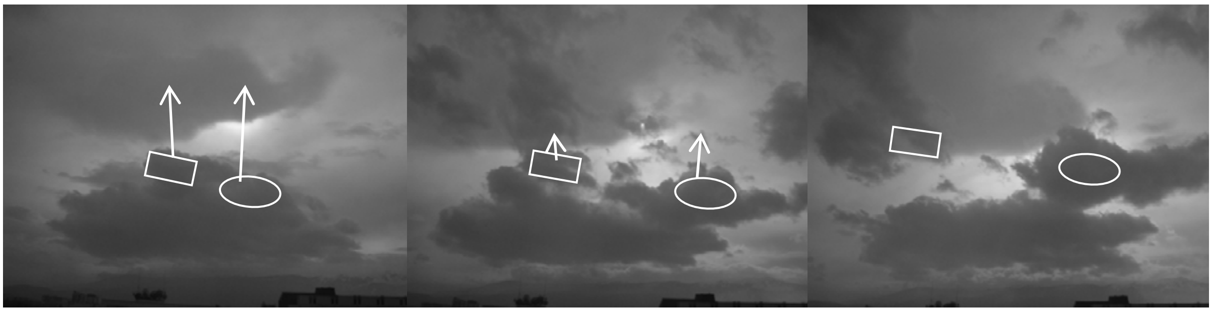

Figure 1. The low clouds rise up approaching (ellipse area) and joining (rectangle area) the upper located cloud. The movement is evident from the position of clouds with respect to the sun. P>norm, slight decreases; humid air RH>60%; improving of the worsened V=6→8 km.

The next example refers to the appearance and development of rainy stratus and stratus-cumulus clouds. The 3 images in Figure 2 are acquired at P<norm =1007 hPa (at sea level), RH<60%=55% that is not as high as usually needed for further new low cloud formation as is shown in the previous example. The rainy stratus and stratus-cumulus clouds are usually located at the upper area of the frames. They look heavy and their low edges become well outlined and thicker. The cloud gradually is getting thicker at the expense of the surface aerosols - the brightness of the transmitted light decreases by more than 70% in the first two pictures. This is related to pumping effect on aerosols below the cloud manifested with further decreasing of RH and improving V. At that time the temperature T becomes higher because of the intensification of the water condensation that is related to the growth of droplets to raindrops and to the beginning of rain showers. During the rain, cloud rarefies that is the optical thickness diminishes – the 3-rd image. The influence of precipitating clouds on the air below finds expression in replenishment of water supplies and increasing of number concentration and the size of near surface aerosols. Actually, cloud dispersion during the rain is accompanied with worsening of V to 6 km and increasing of RH to 72%. This is a display of the opposite interaction – the influence of clouds on the atmospheric parameters beneath. But after the partial dissipation, the cloud still looks "rainy" in the sense mentioned above. At these meteorological conditions – P<norm, high RH and abundance of large in size aerosols below the cloud, i.e. reduced V – the repeated activation of processes of rainy cloud formation and vice versa is observed during the next day or two.

Figure 2. The influence of surface aerosols on the formation of precipitating cloud at P<norm; RH ≤ 60% is displayed as growth and thickening of the latter (first 2 pictures). During the rain, cloud rarefies (3-rd picture).

In the present study, some relations between visible features of clouds and the variations of specific parameters of the atmospheric meteorological conditions have been established. Some macro physical characteristics of clouds such as shape, thickness, motion, etc. closely reflect the variations of meteorological conditions. The remote sensing of the variations of cloud optical properties by means of visible images taken from earth's surface can improve our knowledge of the climatologic importance of atmospheric aerosols and clouds. Also, these methods may be complementary to the satellite imagery.

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