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Transformation of Optical Properties of Tropospheric Aerosols after Rain

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ABSTRACT. Transformation of spectral optical density of tropospheric aerosols within the wavelength range of 0.50 and 0.70 μm has been studied from 12 to 24 hours after rain, each three hour period, in conditions of high humidity (seashore and mountainous zone of Ajara). It has been established that from 12 to 18 hours after rain the concentration of aerosols gradually decreases and the maximum of the range of distribution of aerosols by sizes shifts towards larger particles. After 18 hours a reverse process is observed. A weak selective area of aerosol absorption is detected within the wavelength range of 0.62-0.64 μm and an approximate intensity of its absorption is calculated. The transformation of Ångström formula parameters is determined within the observed period of time.

Key words: *tropospheric aerosols, optical density, wavelength.*

Tropospheric aerosols have a crucial role in the formation of the energetic system of the underlying surface. Having influence on energetic system variation caused by various reasons, their impact may translate into decrease as well as increase of this system [1-3]. The kinetic model of tropospheric aerosols by G. Rozenberg [4-6] is developed on the basis of theoretic assumptions alone and as the author notes, is primarily characteristic of an atmospheric condition which is less saturated with humidity. As is known, theoretic values of optical parameters of aerosols incorporated in the model are compared with the practical parameters twice. The comparison of four parameters of the above-mentioned model (of which the key one was the duration of the existence of submicron aerosols) with the actual ones in the atmospheric conditions of Moscow, yielded fully satisfactory results [6]. The comparison of the key parameter of the model (the duration of the existence of submicron aerosols) with the actual one was also carried out in conditions of high humidity, namely, at the seaside and high mountainous zone of Ajara [7]. The duration of the existence of tropospheric aerosols, described in the model, may vary from 12 hours to 10 days, depending on possible variations of the physical parameters of the atmosphere. The double-checking showed that the duration of existence of anthropogenic as well as background aerosols in summer months is limited to 4 and 5 days, respectively. The above-mentioned paper discussed the concentration of aerosols during 6 hours after rain with 2 hour intervals, whereas thereafter - during seven days - average daily indicators of the concentration were determined. It was found out that during two hours after the rain the aerosol concentration was decreasing and only after that it started increasing, and as said above, reached the maximum value on the 4^{th} and 5^{th} days, which was followed by a sharp decline in the concentration. Further investigation of this process showed that against the background of increasing daily average indicators, significant variations were observed during a single day not only in the concentration of aerosols but also in other optical parameters.

As is well known, physical or optical parameters characteristic of atmospheric aerosols are marked by more stability as compared to the parameters determining the atmospheric condition. The aim of this paper is to determine what the changes are that key parameters characteristic of atmospheric aerosols undergo from 12 to 24 hours after the period they originate. The end of a continuous rain is regarded to be a starting point of origination, whilst the reviewed period is divided into five three-hour intervals.

Complete information on actual data used in this paper, is provided in [8]. Complex experimental studies that were conducted for years at the seaside and high mountainous zone in Ajara included the value of spectral optical density of atmospheric aerosols for a 16 discrete range of wavelengths from 0.37 to 0.99 μm (with centers from 0.493 μm to 0.702 μm), which are insignificantly influenced by the absorption of atmospheric water vapour and ozone. It should be noted that within the indicated range an area of weak absorption of aerosols was observed [9], which is not taken into account in the method of identifying optical density of aerosols.

The changes in optical density of aerosols in the spectral range of 0.493-0.702 μm at 12, 15, 18, 21 and 24 hours after rain is given in Fig.1. Data given in the figure represent averaged values. The total number, according to which the transformation of optical properties of aerosols has been studied, combines 29 cases. The Figure clearly shows that the optical density of aerosols does not increase gradually during 12 - 24 hours after the origination. Optical density gradually increases in almost every range of the wavelength from 12 to 21 hours after its origination. By 24 hours it sharply decreases. This process also occurs in conditions of gradual increase of average daily values of the same parameter [7].

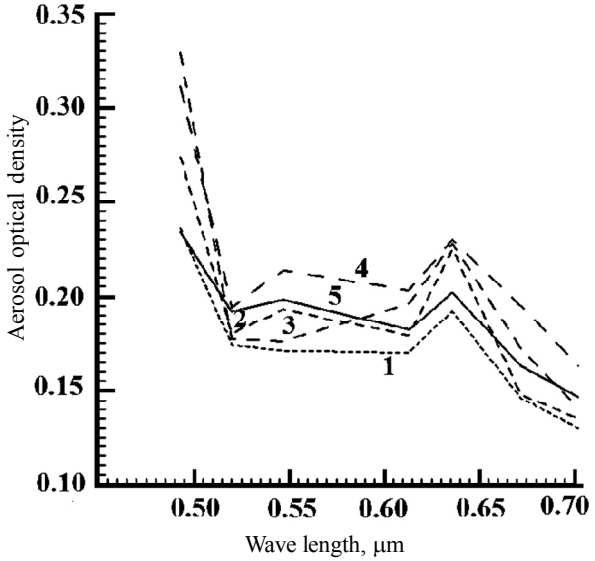

Fig. 1. Spectral optical density of atmospheric aerosols at 12 (1), 15 (2), 18 (3), 21 (4) and 24 hours (5) after rain.

Autocorrelation matrices were built up in accordance with the data used in the paper, which show changes in correlative relation between optical densities of aerosols for given wavelengths by each reviewed hour. Obtained autocorrelation matrices are given in the form of charts in Fig. 2.

If atmospheric aerosols within the reviewed wavelength range are marked with scattering of radial energy alone, i.e. if selective absorption of radial energy by aerosols does not occur, then the correlative relation of optical densities of aerosols of corresponding wavelengths should in general be very high and should gradually decrease along with the increase in the distance between wavelengths. In the case of autocorrelation matrices given in Fig.2, correlation coefficients for matrices 1 and 5, i.e. at 12 and 24 hours after rain, are above 0.8 within the entire range. In the remaining cases their values decrease to 0.6. However, a gradual decrease of correlation coefficients by increasing the distance between wavelengths is not observed in matrices 1 and 5. On the contrary, there are distinguished areas where correlation coefficients sharply decrease. This indicates that in the mentioned areas the impact of aerosols on the radial energy is not limited to scattering alone and a selective absorption of radial energy also takes place. The intensity of absorption should be determined by the size of the decrease in the correlation coefficient.

As is well known, the relation of optical density of aerosols τ_a to the wavelength λ (μm) is often determined

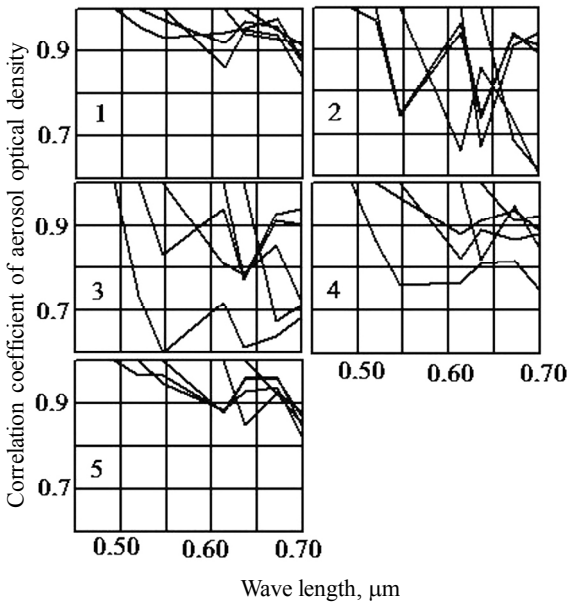

Fig. 2. Change in autocorrelation matrix of spectral optical densities of atmospheric aerosols at 12 (1), 15 (2), 18 (3), 21 (4) and 24 hours (5) after rain.

Table 1

Changes in β and n parameters of formula (1) from 12 to 24 hours after rain

Angstrom formula parameters	Period after rain (hours)				
	12	15	18	21	24
β	0.188	0.242	0.324	0.266	0.141
n	-0.637	-0.517	-0.357	-0.506	-0.840

by the famous Ångström formula:

$$\tau_a = \beta \lambda^{-n} \quad (1)$$

which describes only the scattering process of radial energy on atmospheric aerosols.

As Fig.1 (as well as Fig.2) shows, especially within the area of wavelengths from 0.63 to 0.64 μm, the impact of aerosols on the radial energy is not limited to scattering alone and absorption seems to also take place in this area. We tried to take into account the approximate absorption and to define from three narrow areas of observation, with the centers $\lambda = 0.613$, 0.636 and 0.672 μm, functional relation between the aerosol absorption intensity μ_a and decreased correlation coefficient Δr values:

$$\mu_a = f(\Delta r), \quad (2)$$

where

$$\Delta r = (r_{0.613} + r_{0.672})/2 - r_{0.636}. \quad (3)$$

With the use of formula (3) we determined Δr and corresponding μ_a values for all the five periods after rain and presented formula (2) in circular approximation [10]. It took the following form:

$$\mu_a = 0.09 - 0.28\Delta r \quad (4)$$

Formula (4) was used to calculate that part of the optical density of aerosols which was conditioned by the absorption process and was deducted from an actually derived $\tau_{0.636.}$ Thus, the data used in the paper considered only scattering of radial energy on aerosols. According to the obtained data and by applying least square method [10], β and n parameters were calculated in formula (1) for each period after rain. Their values are given in Table 1 whilst Fig. 3 shows the changes in the optical aerosol density by wavelengths, determined in accordance with these values.

It should be noted that the β parameter of Ångström formula is mainly determined by the concentration of atmospheric aerosols whilst the value of n parameter depends on the distribution range of aerosols by sizes [11, 12]. If this is taken into account, then it turns out that the concentration after rain increases from 12 to 18 hours and thereafter, starts decreasing. The reason why it happens so is that the maximum of the range of distribution by sizes shifts toward large particles, which is absolutely natural and is clearly seen from the change in n parameter.

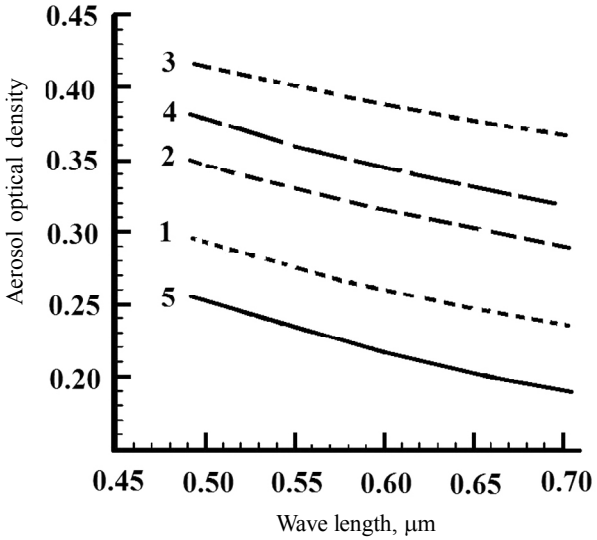

Fig. 3. Change in spectral optical densities of atmospheric aerosols calculated by formula (1) at 12 (1), 15 (2), 18 (3), 21 (4) and 24 hours (5) after rain.

The change in optical densities of atmospheric aerosols by wavelengths given in Fig.3, which is regarded to be a key parameter of the pollution of atmosphere, shows that during 18 hours after rain atmosphere tends to be cleaned. Taking into account the results obtained in the paper [7], the transformation of aerosols after rain can be characterized as follows (rain is the main cleaner of atmosphere from aerosols): during 2-3 hours after rain the cleaning of atmosphere continues; thereafter, until about 18 hours, a process of gradual gathering of aerosols in the atmosphere starts [see, 6]; from 18 to 24 hours pollution decreases due to sedimentation of large particles; then, pollution increases again for 4, 5 days and later it sharply decreases.

Thus, the duration of the existence of tropospheric aerosols, as G. Rozenberg notes, is limited to several days but during the existence, the concentration of aerosols as well as the range of their distribution by sizes experience local decreases against the background of overall increase.

გეოფიზიკა

ტროპოსფერული აეროზოლების ოპტიკური თვისებების ტრანსფორმაცია წვიმის შემდეგ

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(წარმოდგენილია აკადემიის წევრის თ. ჭყონიძის მიერ)

ჭარბი ტენიანობის პირობებში (აჭარის ზღვის სანაპირო და მაღალმთიან ზონაში) შესწავლილია ტროპოსფერული აეროზოლების სპექტრული ოპტიკური სიმკვრივის ცვლილება ტალღის სიგრძის 0.50 – 0.70 მკმ-ის დიაპაზონში, წვიმის შეწყვეტიდან ყოველი სამი საათის შემდეგ, 12-დან 24 საათის განმავლობაში. დადგენილია, რომ წვიმის შეწყვეტის შემდეგ 12-დან 18 საათამდე აეროზოლების კონცენტრაცია თანდათანობით შემცირებას განიცდის და აეროზოლების ზომების მიხედვით განაწილების სპექტრის მაქსიმუმი გადაინაცვლებს შედარებით მსხვილი ზომებისკენ. 18 საათის შემდეგ დაიკვირვება შებრუნებული პროცესი. შემჩნეულია აეროზოლების შთანთქმის სუსტი სელექტიური უბანი ტალღის სიგრძის 0.62-0.64 მკმ-ის დიაპაზონში და მიახლოებით გამოთვლილია მისი შთანთქმის ინტენსიურობა. განსაზღვრულია ანგსტრემის ფორმულის პარამეტრების ტრანსფორმაცია დროის განხილულ პერიოდში.

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