Variations of aerosol optical thickness, water vapor and Ångström parameter over the semi-arid zone of Tajikistan

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Abstract. The article describes the results of measurements that were carried out systematically during 2010-2017 at the AERONET station in Dushanbe. The data on the changes of aerosol optical thickness (AOT), moisture content and Ångström parameter are described. The seasonal and annual variations of these quantities were analyzed. The regularities of repeatability histograms as statistical characteristics of the atmospheric parameters were studied.

1 Introduction

Tajikistan is located in the southern mountainous part of Central Asia between 36°40'N and 41°05'N and 67°31'E and 75°14'E and stretches for 700 km from west to east and for 350 km from north to south. Mountains occupy over 93% of the country's territory and more than half of the country is more than 3,000 meters above sea level. These areas are not suitable for agriculture due to extreme climatic conditions and landscapes which consists predominantly of rocks, glaciers and highlands. Absolute altitudes vary from 300 m to 7,495 m. The country is landlocked in continent from seas and is distant to oceans. Climate conditions are diverse ranging from both cold and hot arid areas to places with a humid subtropical climate. The city of Dushanbe, where research was conducted, is located in a mountain valley and is surrounded by low mountains.

The emission of natural and anthropogenic aerosol into the atmosphere is one of the most important factors governing climate change. Observations of the optical and microphysical characteristics of the atmosphere during a dust storm (dust mist) make it possible to estimate the dust effect on the thermal regime of near ground air layers. Particles with sub micrometer sizes, which usually determine the degree of atmospheric opacity during dust storms and dust haze, absorb solar radiation stronger in the visible spectral region than in thermal spectral region [1, 2].

Dust aerosol in the arid zone and on the desertified territories, where conditions for erosion type blow off of dust are created, has been studied for many years.
A systematic and thorough study of this problem began with a 1989 Soviet-American experiment in Tajikistan organized by G.S. Golitsyn and aimed at studying the arid aerosol [1]. To date, a number of detailed studies of different aspects of arid aerosol have been performed using modern instrumentation [2–4]. In particular, measurements of differential particle number concentrations are used to retrieve the particle size distribution function of aerosol generated by the sand wind flow [2]. The synchronous measurements of aerosol concentration and turbulent wind pulsations were used to study the mechanisms of vertical aerosol blow off.

2 Observations and data

The annually average number of days with mist in Dushanbe reaches 12, of which 7 days have heavy dust, with the visibility range falling to less than 2 km. The number of days with moderate to heavy mist in the record high year of 2001 from June to November was 29.

During the summertime dust mist, air is 3–8°C cooler than in fair weather. These phenomena markedly affect the climate, ecology, and human health, indicating the importance of the problem.

The AERONET (AErosol RObotic NETwork) station in Dushanbe is equipped with a CIMEL CE-318B sun photometer and is operated since 2010 thanks to a joint collaboration with Brent N. Holben (AERONET Project Head, National Aeronautics and Space Administration (NASA) Goddard Space Flight Center, USA), Prof. Philippe Goloub and Dr. Oleg Dubovik (Laboratoire d'Optique Atmosphérique, Université Lille, France) (https://aeronet.gsfc.nasa.gov/new_web/photo_db_v3/Dushanbe.html). The field site at the Physical Technical Institute of the Academy of Science of Tajikistan is located at 38°33'34"N, 68°51'22"E at an altitude of 864 m ASL [5]. The CIMEL sun photometer measures at 8 wavelengths these years.

This article presents the results of the analysis of the variation of the aerosol optical thickness (AOT) water vapor and Ångström parameter over the semi-arid zone of Tajikistan (Dushanbe) for 73570 series of measurements

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obtained at the AERONET site of Dushanbe, at the Atmospheric Physics Laboratory of the Physical-Technical Institute of the Academy of Science of Tajikistan.

3 Results

Figure 1 shows the monthly change in AOT for the period from July 2010 to December 2017. The highs correspond to the period June to November, and the minimums correspond to January to May each year. High values of AOT in the atmosphere of the south-central part of the country are associated with dust intrusions from the south-western borders which has a long-distance source of generation [6-10].

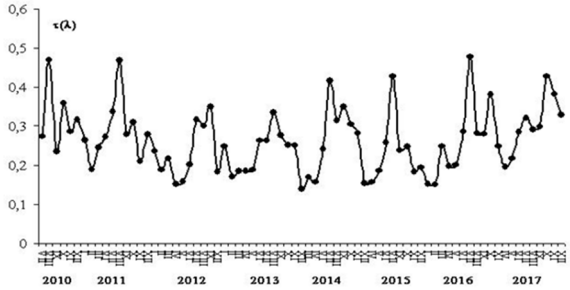

Figure 1. Monthly variation of AOT during 2010-2017.

In the seasonal variation of AOT (Fig. 2), high values are observed in the summer-autumn period of 2010-2017. The autumn-summer period of 2013 and 2015 in this series is more pure than in other years, which is possibly due to the reduction of dust incursions in these years.

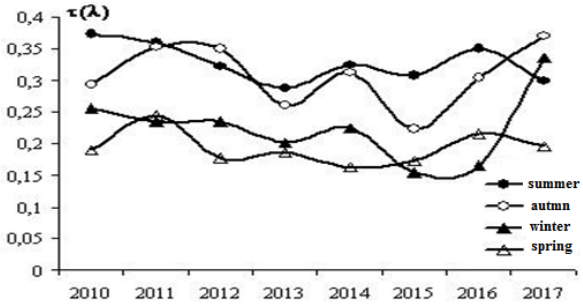

Figure 2. Seasonal variations of AOT in the period 2010-2017.

In the inter-annual dynamics of AOT changes (Fig. 3) it was established that during the period 2010-2017 the most polluted years were 2010 and 2017 the cleanest years 2012, 2013, and 2015, and it is evident that practically the same level of pollution is observed in these years. The calculated correlation coefficient between AOT and water vapor content was 0.37, Ångström parameter -0.43 and average annual temperature 0.75 in this period. The course of changes in the AOT of the soil repeats the dynamics of the inter-annual change in the mean annual temperature.

The inter-annual dynamics of AOT changes during the period 2010-2017 (Fig. 3) show that the most polluted years were 2010 and 2017 and the cleanest years were 2012, 2013, and 2015, and it is evident that practically the same level of pollution is observed in mean annual temperature.

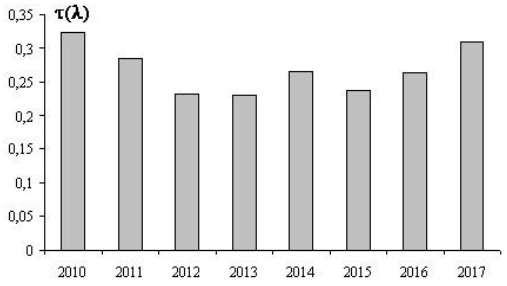

Figure 3. The annual variation of AOT during 2010-2017.

The calculated correlation coefficient between AOT and water vapor content was 0.37, between AOT and Ångström parameter -0.43 and between AOT and average annual temperature 0.75 in this period.

In Fig. 4, the monthly change in the content of water vapor in the atmosphere is presented.

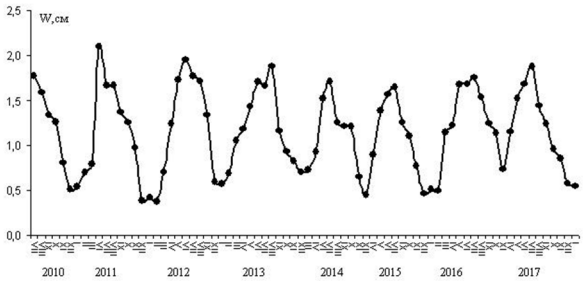

Figure 4. The monthly variation of water vapor content in the vertical column of the atmosphere for the period 2010-2017.

In the seasonal course (Fig. 5), the changes in the water vapor content are set at a maximum in the summer period and at the minimum in the winter period, with a failure in 2014.

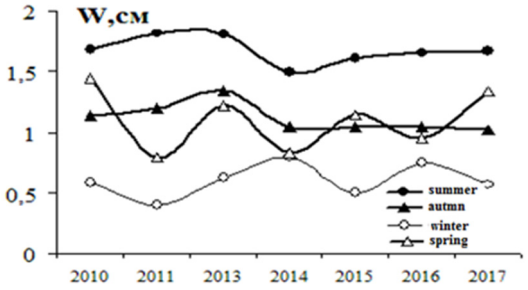

Figure 5. The seasonal change of the humidity in the vertical column of the atmosphere for 2010-2017 years.

In the inter-annual variation of the water vapor content, the minimum was registered in 2014 and the maximum in 2017 (Fig. 6). The correlation coefficient between the water vapor content in the vertical column of the atmosphere with the AOT is positive (0.37), with the Ångström parameter negative (-0.25), and with an average annual temperature significant (0.75).

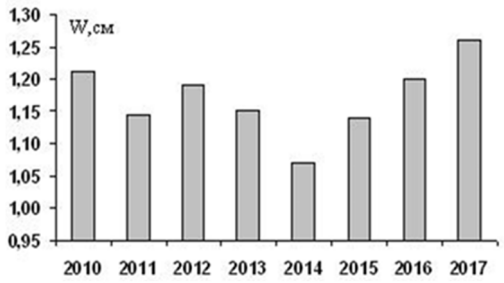

Figure 6. The inter-annual variation of the water vapor content in the vertical column of the atmosphere in 2010-2017.

The minimums of humidity were observed in the winter period for 2011 and 2015. The maximum in the autumn period was registered in 2013. The autumn period for the remaining years has almost identical values. The spring period of the change has a sinusoidal character, antiphase with the winter period begins in 2013.

Maximum amplitude in July, and a minimum in December-February and minimal in 2014, which is due to the dominant role of the coarse particle fraction. The correlation coefficient of the Ångström parameter with AOT is -0.43, with the water vapor content -0.25 and with the average annual temperature 0.01.

Figure 7 shows the changes in the average monthly values of the Ångström parameter for the period 2010-2017. High values are observed in December and February, which is due to the presence of a submicron aerosol fraction in the atmosphere and low values of the Ångström parameter in June-July with the dominant contribution from the coarse aerosol fraction.

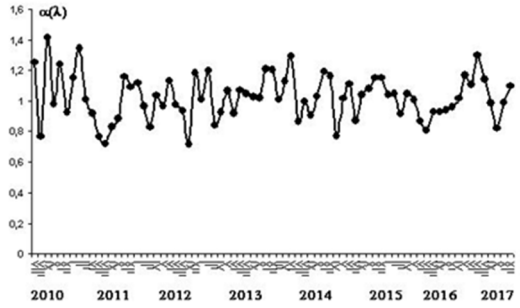

Figure 7. Inter-annual variation of the average monthly Ångström parameter for the period 2010-2017.

The seasonal variance of the Ångström parameter (Fig. 8) shows that high values occur in the cold season and low values in the warm season. However, this pattern is not always fulfilled, since seasonal variations have instability, which indicates the variation of large-dispersed and submicron fractions of the aerosol in the atmosphere of Dushanbe city.

In the inter-annual course of the Ångström parameter for the period 2010-2017, high values were found in 2010 and 2017, which is probably due to the dominant role of the submicron fraction of particles (Fig. 9).

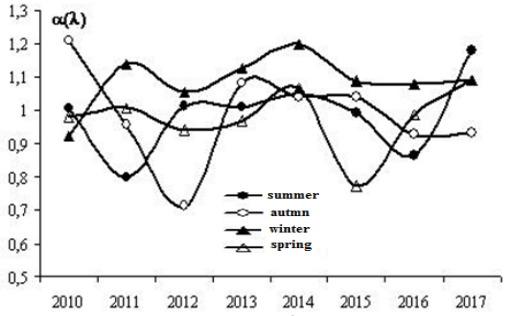

Figure 8. Seasonal variation of the Ångström parameter for the period 2010-2017.

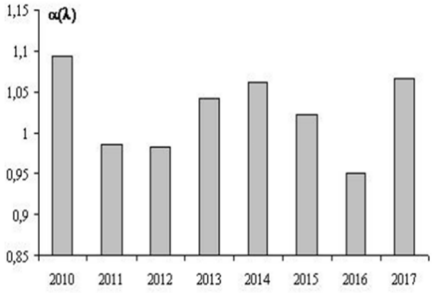

Figure 9. Inter-annual change of the Ångström parameter for the period 2010-2017.

4 Summary

The results show that there is an inter-annual dependence of atmospheric parameters (AOT, moisture content, Ångström parameter) associated with the climatic features of each year, as well as intra-annual and seasonal variability of these parameters, determined by the seasonal change in dust content of the air. An increase in the size of dust particles of the aerosol and an increase in AOT during the season of dust intrusions (summer and autumn), together with an increase in the moisture content of air in the warm season, naturally lead to the corresponding seasonal variation of averaged values of parameters. The overlap of climatic and seasonal factors results in the observed rather complex dynamics of parameters.

Forecasting opportunities of atmospheric parameters are limited to the very complex problems of long-term weather forecasts and dust intrusion forecasts. Climate changes create complex inter-annual trends in atmospheric parameters. Note that the parameters used in the article are preliminary and are not subject to systematic mathematical processing of associated errors, for example, with the solution of the inverse scattering problem. This confirms their value, significance and relevance for assessing the state of the atmosphere.

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