SMOKE AEROSOLS OVER MOLDOVA FROM THE FIRES OCCURRED IN THE WESTERN RUSSIA, BELARUS AND UKRAINE DURING THE AUGUST – SEPTEMBER, 2002

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Abstract

Results of the column-integrated aerosol optical and microphysical properties measurements carried out with a sunphotometer Cimel-318 at the ground-based station over Kishinev, Moldova are presented. Station was incorporated into the globally distributed Aerosol Robotic Network (AERONET), managed by NASA/GSFC. Spectral aerosol optical thicknesses (AOT) retrieved from sunphotometer measurements throughout the period of August-September 2002 are presented in comparison with the multi-year statistics of AOTs retrieved from measurements made during the period 1999-2003. August-September 2002 was characterized by intrusion of air masses with smoke particles in Moldova from Russia, Belarus and Ukraine regions with numerous loci of forest and peat fires. It was observed large influence of smoke particles on AOT values variability. In particular, on 11 September, daily average value of AOT at wavelength λ=500 nm $<\tau_a(500)>$ was the highest one ever measured at the Kishinev site and reached value of ~2.16 .

Keywords: aerosol optical thickness (AOT), smoke particles, volume distribution function

Introduction

Complex interaction of the synoptic processes and the processes that initially form aerosols both with anthropogenic and natural origin results in variability of the optical properties of atmospheric aerosols. Biomass burnings are the most numerous and frequent sources generating smoke aerosols all around the world. Air masses with smoke particulates exert a large influence upon the aerosol optical properties both in regions of their origination and in regions where the smoke is transported due to air masses movement. To receive comprehensive information about these properties of the atmospheric aerosols there are widely used ground-based measuring platforms. In this paper it is investigated the variation of atmospheric aerosol optical properties derived from the direct Sun and sky radiance measurements by using multiwavelength sunphotometer. These properties are analyzed in connection with the influence of the smoke particles long-distance transported from the west regions of Russia, Belarus and Ukraine where numerous of forest and peat fires were observed from August to September, 2002.

Measurement approach and results

Column-integrated aerosol optical and microphysical parameters, such as AOT $\tau_a(\lambda)$, single scattering albedo (SSA) $\omega_{a,\lambda}$, real *n* and imaginary *k* parts of refractive index of aerosol matter, and volume size distributions dV/dlnR, have been derived from the direct Sun and sky radiance measurements in cloudless atmosphere. These measurements have been carried out at the Kishinev site of observation, Moldova (47.0013°N, 28.8156°E; 205 m a.s.l.). This site is in operation within the framework of the Aerosol Robotic Network (AERONET), managed by NASA/GSFC. AERONET is globally distributed ground based network of radiometers for continuous monitoring of the aerosol optical properties [1]. The network instrument is an automatic Sun/sky scanning radiometer, or sun photometer CIMEL CE-318, which makes direct Sun measurements in seven spectral channels at 340, 380, 440, 500, 670, 870, and 1020 nm and measurements of the sky radiance in the solar almucantar in four spectral channels within the spectral range from 440 nm to 1020 nm. Channel at 940 nm is used to retrieve precipitable water vapour content. Uncertainty in AOT $\tau_a(\lambda)$ measurements consists of value $\delta\tau_a(\lambda)$= 0.01-0.02 and has spectral dependence with high errors in the UV spectral range. Data sets obtained from the direct Sun and sky radiance measurements were used to determine variation of the columnar aerosol optical and microphysical properties. Columnar optical and microphysical properties of aerosol particles are routinely computed with the AERONET smart inversion algorithms [2].

This instrumentation was successfully used for monitoring of the variability optical properties of the atmosphere at the Kishinev site during the fire events occurred in west regions of Russia, Belarus and Ukraine from August to September, 2002. In spite of the fact that the centers with the extensive biomass burning are located far away from the site of observation in Kishinev, smoke aerosols generated in fires were transported by air masses and, finally, smoke had influenced upon the optical properties over the site. The complexity of the problem for studying aerosol optical properties variability is defined by following factors: (i) air masses pollution both from the outer industrial and local rural centers along the long path of air masses transport; (ii) transformation due to particle aging, gas-to-particle interaction, and coarse mode sedimentation; (iii) local meteorological conditions (e.g., particle condensation growth). Figures 1 and 2 show composite image the smoke polluted region obtained from the satellite platform TERRA on August 25, 2002 and from NOAA -12, -15, -16 and -17 composite image of extent of smoke of fires in Russia, Ukraine and Belarus on September 8, 2002, respectively. The site of observation is placed in the region where the air masses with smoke particles crossed it due to the long-path transport to the Moldova from the west regions of Russia, Belarus and Ukraine, where numerous loci of forest and peat fires were observed. Some of them, which were the most intensive, have occurred in Moscow region from the 5 to 7 September, 2002.

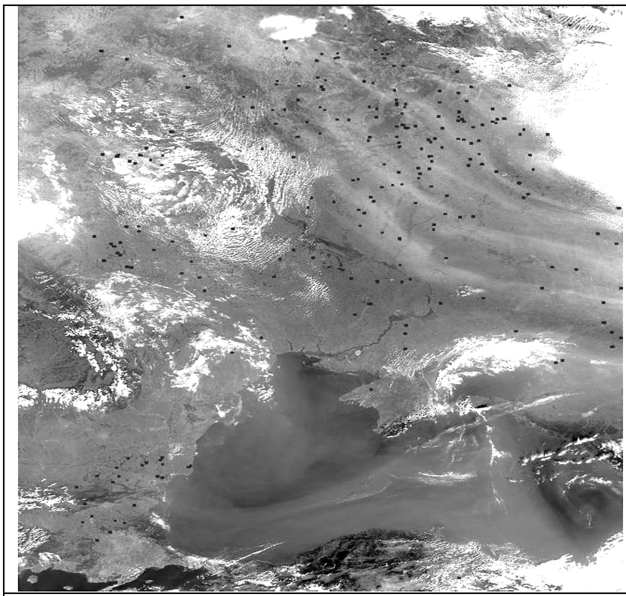

Figure 1. Image of the smoke polluted region obtained from the satellite platform TERRA (time: 0900UTC, date: August 25, 2002). Source: http://rapidfire.sci.gsfc.nasa.gov/

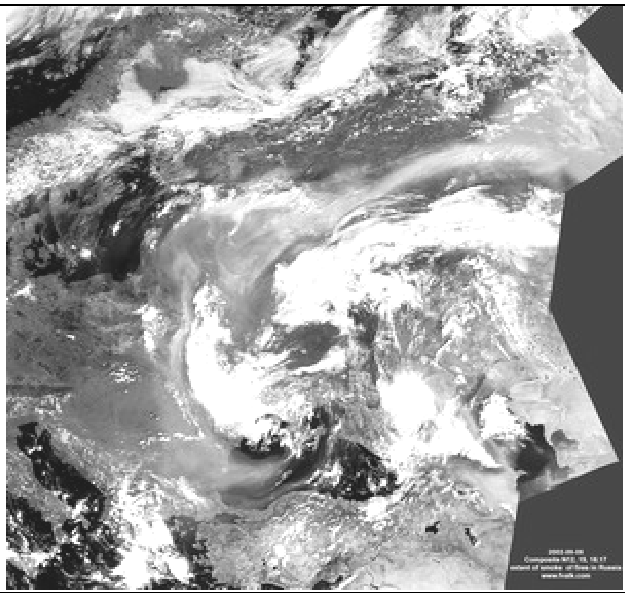

Figure 2. NOAA -12, -15, -16 and -17 composite image of extent of smoke of fires in Russia, Ukraine and Belarus (date: September 8, 2002). Source: http://www.fvalk.com.

Due to the complex synoptic processes these air masses were mostly transported in the south direction. The history of air masses transported to the Moldova from the Russia, Belarus and Ukraine is clearly seen from the 5-days back trajectories analysis using HYSPLIT model (http://www.arl.noaa.gov/ready/hysplit4.html) (Figure 3).

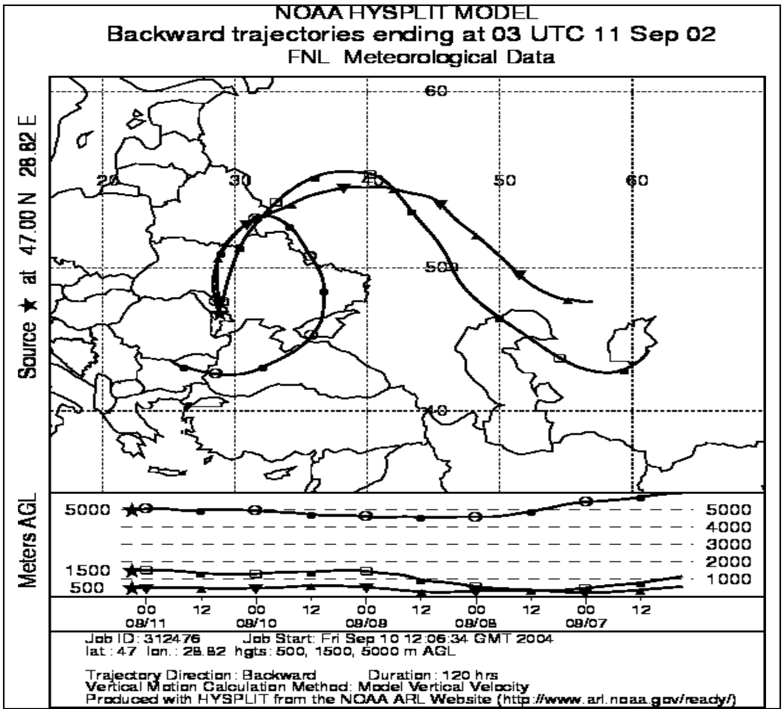

Figure 3. Five-days back trajectories chart from the HYSPLIT model for the Kishinev site (Sep. 11, 2002; time: 0300 UTC). End point is matched to the position of the Kishinev site and is marked by asterisk.

August and September, 2002 were characterized as months with highly values of aerosol optical thickness $<\tau_{a,\lambda}>$ for all wavelengths from 340 nm through 1020 nm. But in September AOT values reached their maximum values ever registered both in Kishinev and Moscow sites for the period of observation from 1999 to 2002. Days with high values of AOT were the following: for Moscow site, placed in the vicinity of peat and forest fires, it was the 7 September, and for Kishinev site, placed at the distance of ~1400 km far from the regions were fires occurred, it was the

11 September, when the air masses with smoke particles have reached the Moldova and modified optical properties of atmosphere.

At the Kishinev site, the September 11, 2002 was characterized as a day with maximum variability of aerosol optical and microphysical properties due to intrusion of air masses with smoke particles. The "activity" of this month is clearly seen from the comparison of the time series of yearly mean (for 2002) AOT $<\tau_a(500)>$ and time series of yearly combined mean (for the period from 1999 to 2003) AOT $<\tau_a(500)>$ retrieved from the measurements made at this site (Figure 4). Monthly average of AOT $<\tau_a(500)>$ for September reached the value of ~0.58±0.56 with high value of standard deviation, which characterizes the instability of optical properties during this period of observation. For comparison, $<\tau_a(500)>$ retrieved from the period of observation from 1999 to 2003, was ~ 0.34±0.36 . More detailed vision of such "activity" is clearly seen from the time series of daily mean values of aerosol optical thickness $<\tau_a(500)>$ retrieved from measurements made at the Kishinev site from August-September(Figure 5). The pronounced spike at the time series is attributed to the September 11, 2002.

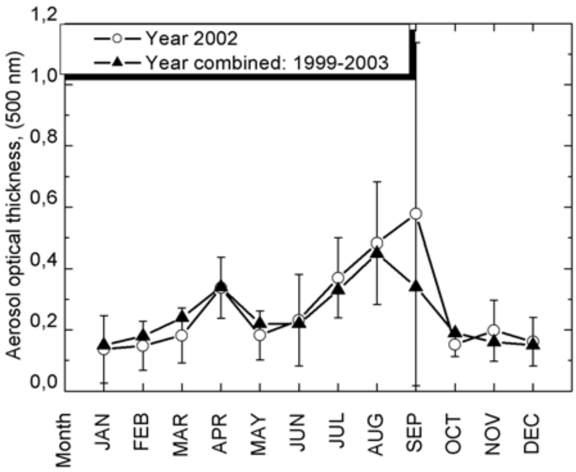

Figure 4. Yearly mean (for 2002) and yearly combined mean (for 1999-2003) aerosol optical thickness $<\tau_a(500)>$ variation measured at the Kishinev site.

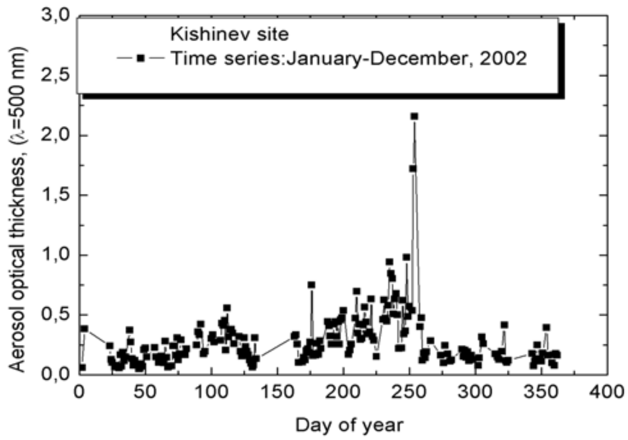

Figure 5. Time series for daily mean values of aerosol optical thickness $<\tau_a(500)>$ retrieved from measurements made at the Kishinev site. Period of observation: January-December, 2002.

Spectral variation of monthly average values of AOT $<\tau_a(\lambda)>$ at wavelengths from 340 nm to 1020 nm for the period of observation for August-September, 2002 is shown in Figure 6.

Monthly mean values AOT $<\tau_{a,\lambda}>$ retrieved for September are higher than the analogous ones for the August. Year mean values $<\tau_{a,\lambda}>$ for year of 2002 are smaller than for the August-September period of observation and this year mean spectral dependence of AOT is also shown on Figure 6. Daily mean values of AOT $<\tau_{a,\lambda}>$ retrieved on September 7 at the Moscow site and on September 11 at the Kishinev site, are very high and show spectral variation owing to the presence of small particles. In particular, on 11 September, daily average value of AOT $<\tau_a(500)>$ was the highest one ever measured at the Kishinev site and reached value of ~2.16 and for selected point measurement made at 06:43 GMT AOT $\tau_a(500)$ was ~2.77. For comparison, measurements carried out at the Moscow site (in the vicinity of fires loci) on 7 September, gave daily mean value of AOT $<\tau_a(500)>$ =2.15. Higher values of daily mean AOT $<\tau_{a,\lambda}>$ for short wavelengths region in Moscow case are probably attributed to high absorption of fresh smoke particulate matter.

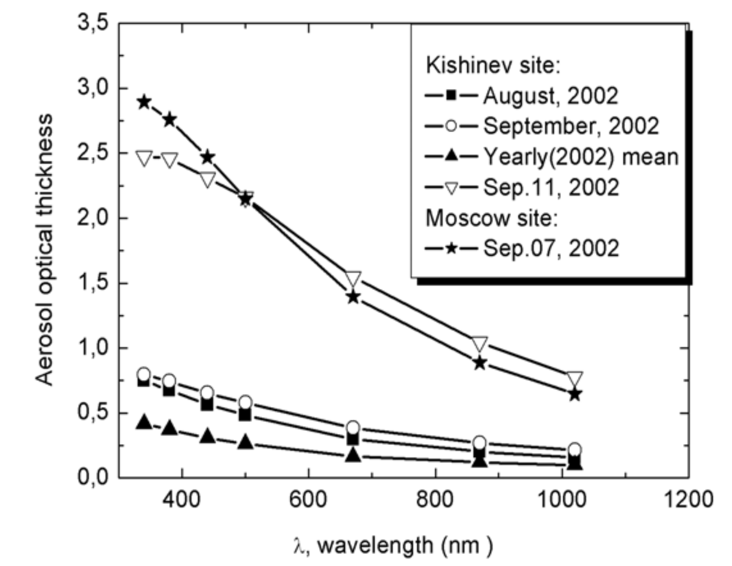

Figure 6. Spectral dependence of monthly average of aerosol optical thickness $<\tau_a(\lambda)>$ for August and September of 2002, yearly mean (for 2002), and single measurements made on September 11, 2002 at the Kishinev site and on September 7, 2002 at the Moscow site .

Retrieved daily average values of SSA $\omega_{a,\lambda}$ for the Kishinev case have no spectral variation: $\omega_{a,\lambda}$ reached value of ~0.99 on 11 September. Small value of imaginary part of refractive index k~0.0012 with minor spectral dependence was also retrieved on 11 September. The analogous values retrieved at the Moscow site on 5, 6 and 7 September, showed variability of $\omega_{a,\lambda}$ from 0.94 to 0.97 with small spectral dependence. Measurements carried out at the Moscow site on 7 September, gave values of $\omega_{a,\lambda}$ ~ 0.94-0.96 with $<\tau_a(500)>$ =2.15, and k~ 0.0064-0.0069. This was due to the presence of fresh smoke particles. Low values of ω_λ were due to smaller particle size of fine mode and larger value of k because of high content of black carbon in composition of particulate matter [3]. Real part of retrieved refractive indices n were ~1.49 (with little spectral dependence) and ~1.51-1.55 for Kishinev and Moscow case, respectively. Low values of n and k , and high value of SSA $\omega_{a,\lambda}$ for the Kishinev case were due to hygroscopic growth of smoke particles because of particulate matter may contain sulfur from smoldering combustion of peats in Moscow region. In particular, on 11 September, relative humidity (RH) was 79% at the Kishinev site that confirms findings.

Volume size distributions were retrieved from the sky radiance measurements in almucantar by using inversion procedures [2]. Monthly average (for September 2002) and daily mean of column volume size distributions retrieved from the combined direct Sun and sky radiance (in the solar almucantar) measurements made on September 11, 2002 at the Kishinev site and on September 7, 2002 at the Moscow site are shown on Figure 7. The contribution of the fine mode into the volume size distribution for September 11 is clearly revealed from Figure 7. During a few days before the September 11, the fine mode radius has enlarged from 0.16 μm to 0.26 μm.

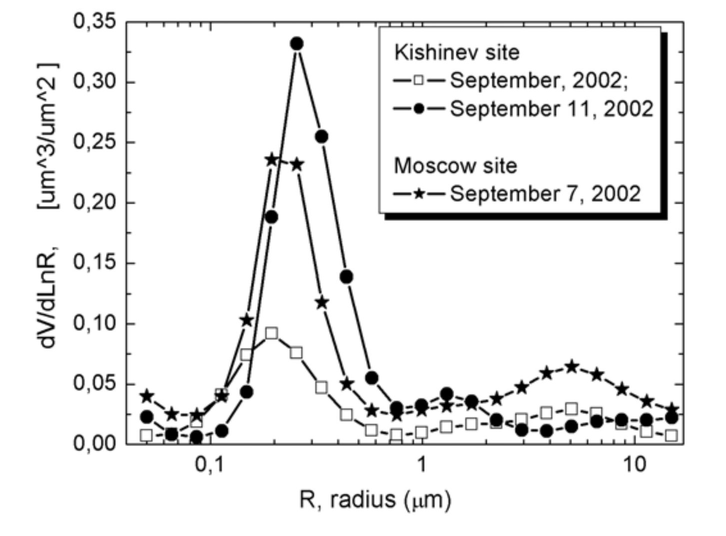

Figure 7. Monthly average (for September 2002) and daily mean column volume size distributions retrieved from the combined direct Sun and sky radiance (in the solar almucantar) measurements made on September 11, 2002 at the Kishinev site and on September 7, 2002 at the Moscow site .

Probably this was due to combination of essential factors such as hygroscopic growth, smoke aging, and mixing with the urban/industrial pollutions during the long-path transport from the west regions of the Russia and other countries along this path. In Moscow case fine mode radius reached the value ~0.19 μm on September 7.

Time series of retrieved volume concentration C_V and effective radius R_{eff} [4] for "fine" and "coarse" modes are shown in Figures 8 and 9, respectively. These parameters, C_V and R_{eff}, were retrieved from the direct Sun and sky almucantar measurements made at the Kishinev site. The presence of the strong spike in dependencies of C_V (Figure 8) and R_{eff} (Figure 9) for fine mode may be prescribed to the prevailing contribution of the smoke aerosol partially transformed during the transport and modified by local weather conditions.

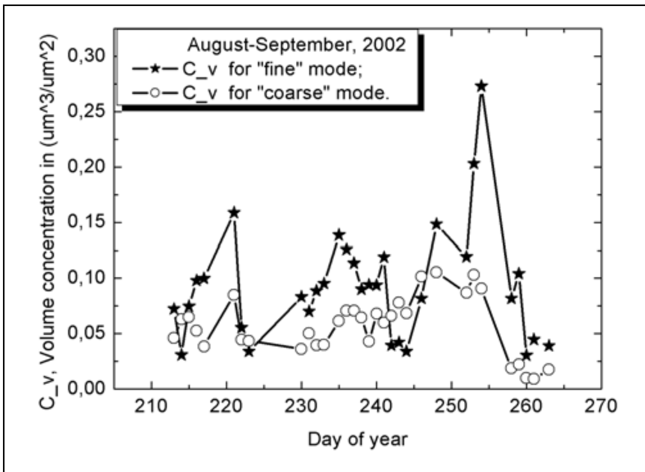

Figure 8. Time series of retrieved volume concentrations C_V for "fine" and "coarse" modes of volume size distribution functions. Period of observation: August-September, 2002.

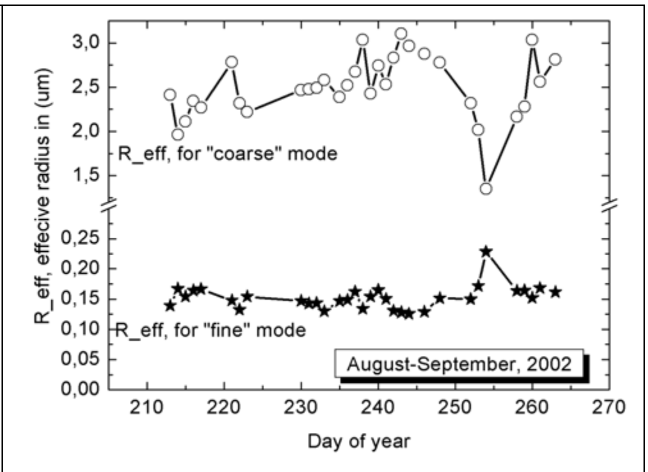

Figure 9. Time series of retrieved effective radii R_{eff} for "fine" and "coarse" modes of volume size distribution functions. Period of observation: August-September, 2002.

Conclusions

The paper shows that the smoke intrusion may cause essential variation of the columnar atmospheric optical and microphysical parameters. This influence is attributed to the amount of smoke particles transported by air masses from loci of forest and peat fires in west regions of the Russia and other countries along the path of transportation. Column volume size distributions of smoke particles are characterized by prevailing contribution of particles with fine mode ~0.16-0.26 μm. On 11 September, 2002 daily average value of AOT $<\tau_a(500)>$ was the highest one ever measured at the Kishinev site and reached value of ~2.16. This day was characterized as a day with maximum variability of aerosol optical and microphysical properties due to intrusion of air masses with smoke particles. Monthly average values of AOT $<\tau_a(500)>$ for September 2002 and multiyear period 1999-2003 were ~0.58±0.56 and ~ 0.34±0.36, respectively. On 11 September, retrieved daily average value of SSA $\omega_{a,\lambda}$ for the Kishinev case was $\omega_{a,\lambda}$ =0.99 having no spectral variation; real and imaginary parts of refractive index were n~1.49 (with little spectral dependence) and k~0.0012 (with minor spectral dependence). Both column-integrated volume size distributions and optical parameters of smoke particles are changed due to hygroscopic growth, smoke aging, and smoke mixing with the urban/industrial pollutions during the long-path transport.

Acknowledgements

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