MONITORING OF AEROSOL OPTICAL PROPERTIES, TOTAL COLUMN OZONE CONTENT, AND SOLAR UV-B ERYTHEMAL IRRADIANCE OVER THE KISHINEV

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Abstract

Results of the aerosol optical properties, total column ozone content and UV-B erythemal irradiance measurements carried out at the ground-based station over Kishinev, Moldova are presented. Simultaneous observations were performed with a sunphotometer Cimel-318, hand-held ozonemeter MICROTOPS II and UV-B broadband sensors which are a part of radiometric complex. Station was incorporated into the globally distributed Aerosol Robotic Network (AERONET), managed by NASA/GSFC. Spectral aerosol optical thicknesses retrieved from sunphotometer measurements throughout the period of 1999-2003 are presented. One year measurements of total column ozone carried out at the station are presented in comparison with the multi-year statistics retrieved from Earth Probe Total Ozone Mapping Spectrometer satellite platform measurements. Seasonal variation of monthly totals and diurnal variations of global and diffuse components of solar UV-B erythemal irradiances measured at the Kishinev site are presented.

Keywords: aerosol optical thickness, column ozone, UV-B erythemal radiation

Introduction

The problem concerning the influence of the radiative factors upon the circulation of the atmosphere and related with further climatic changes holds a prominent place in studying of the global atmospheric processes and energy balance of the atmosphere. Growing rate of the industry development and increasing number of the means of transport together with the natural hazard events exert an essential influence on atmosphere of the Earth modifying it structure, properties and components, which are gases and aerosol particles, respectively. Another essential aspect consists in studying the role of solar UV-B erythemal radiation, total column ozone content and atmospheric aerosol, and their influence upon the human health and biosphere systems. In this connection, ground-based solar radiation monitoring stations are of a particular of interest to obtain an exhaustive and reliable information about the radiation field on the earth surface, aerosol optical and microphysical properties, and column ozone content.

Measurement Approach

All data concerning the aerosol optical properties presented in this study were acquired with the Sun/sky radiometer Cimel CE-318 (France), which is now in operation at the Kishinev site (Figure 1) within the framework of the Aerosol Robotic Network (AERONET) program, managed by NASA/GSFC. This program is dealt with the cooperative investigations of the atmospheric aerosol optical properties in global network. Kishinev site has been included in this network from the September 1999. The automatic Sun and sky scanning spectral radiometer, or sunphotometer Cimel CE-318, is a backbone radiometric instrumentation for routine site measurements, which has been designed and realized to be a very accurate sunphotometer with all features of field instrument: motorized, portable, autonomous (solar powered) and automatic. Sunphotometer 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. More detailed instrument specification, measurement sequences, data quality control and accuracy are described in [1-3]. Columnar optical and microphysical properties of aerosol particles in cloud free atmosphere are routinely computed with the AERONET smart inversion algorithms [4,5] from the data sets obtained from the direct Sun and sky radiance measurements and preliminary processed on cloud screening and quality control [3].

On September 2003, for the first time in Moldova it was developed and established a ground-based multifunctional radiometric complex. Complex is composed from the state-of-the-art solar radiation sensors, data logger CR10X-4M and automatic solar tracker unit 2AP BD (Kipp&Zonen) and was separately assembled in stationary and moving platforms (Figure 1). This radiometric complex is used for long-term continuous monitoring of solar irradiance at the Earth’s surface in a wide wavelength bands from UV to IR. In particular, to measure solar UV-B erythemal global and diffuse irradiance it is used UV-S-B-C sensor (bandwidth of 280-315 nm). Sunphotometer was incorporated into the complex (Figure 1) with the aim to retrieve aerosol optical properties from direct Sun and sky radiance measurements in the almucantar at the site of observation. Both the multifunctional radiometric complex and sunphotometer were placed at rooftop of the Institute of Applied Physics building, which is situated in an urban environment of the Kishinev city, Moldova (φ=47.0013^{0}N, λ_o=28.8156^{0}E, h=205 m a.s.l).

Since July 2003 total column ozone content measurements have been regularly carrying out at the Kishinev site of observation. Ozone measurements are made with the hand-held MICROTOPS II Ozonemeter (Solar Light Co.)[6]. All the data sets are supplemented with the main meteorological observables measured with the automatic weather station MiniMet (Figure 1) mounted on the building roof near the radiometric complex.

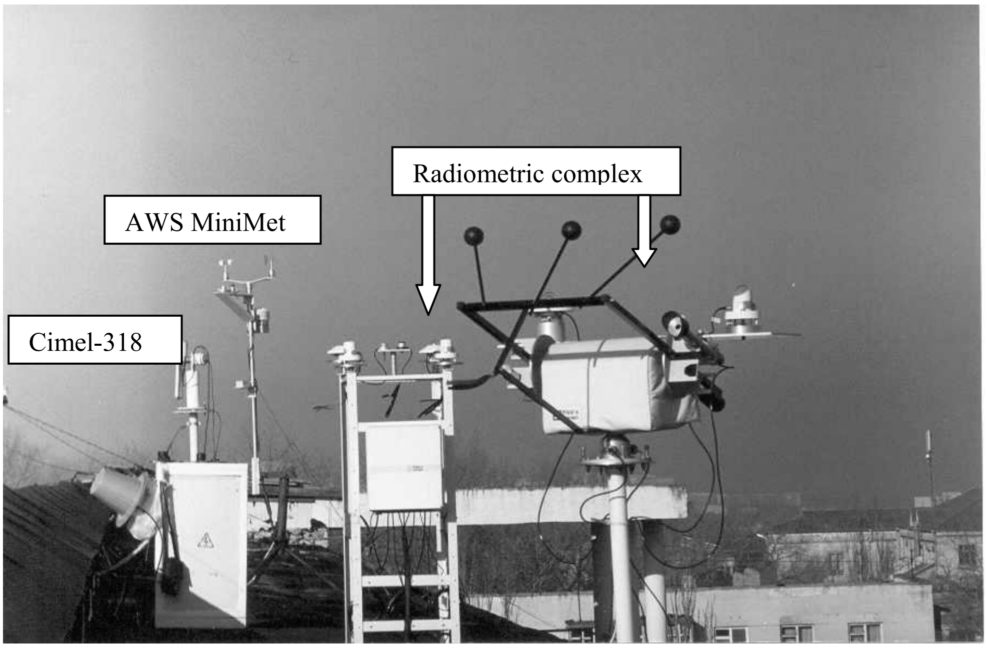

Figure 1. Ground-based multifunctional radiometric complex with operating sunphotometer Cimel CE-318 and weather station MiniMet at the Kishinev site (φ=47.0013^{0}N, λ_o=28.8156^{0}E, h=205 m a.s.l).

Results

Multi-year combined statistics (for 1999-2003) of average values of the aerosol optical thickness (AOT) $<\tau_a(500)>$ retrieved from direct sun radiance measurements made at the Kishinev site is shown in Figure 2. Year (for 2003-2004) mean values of the aerosol optical thickness $<\tau_a(500)>$ with standard deviations σ are also presented in this Figure. In general, this year mean $<\tau_a(500)>$ dependence has the resemblance with the multi-year means except for the January-February and May months, which are characterized by large values both $<\tau_a(500)>$ and their related σ due to unstable weather conditions in the period under observation. Seasonal variability of spectral aerosol optical thickness $<\tau_{a,\lambda}>$ retrieved from direct sun measurements for 2003-2004 has well-defined spectral dependence shown in Figure 3. Autumn period is characterized by low values of AOT $<\tau_{a,\lambda}>$ with $<\tau_a(500)>$ =0.17. At the same time spring and summer periods have higher value of AOT, $<\tau_a(500)>$ =0.24 and higher values of AOT $<\tau_{a,\lambda}>$ ~ 0.38-0.40 at shorter wavelengths in comparison with the values $<\tau_{a,\lambda}>$ ~ 0.23-0.31 retrieved for autumn and winter periods.

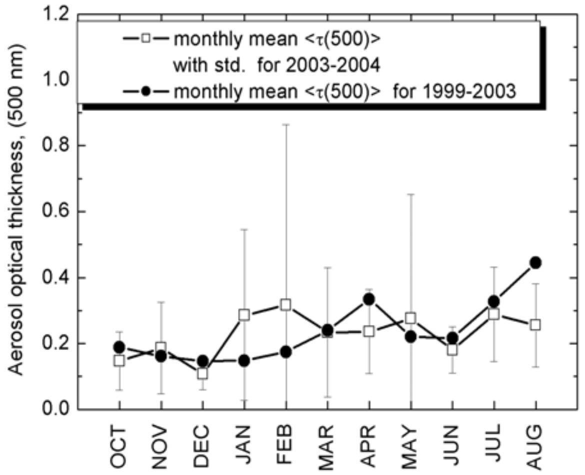

Figure 2. Multi-year combined (for 1999-2003) and year (for 2003-2004) mean values of the aerosol optical thickness $<\tau_a(500)>$ for cloud free atmosphere retrieved from direct sun radiance measurements made at the Kishinev site.

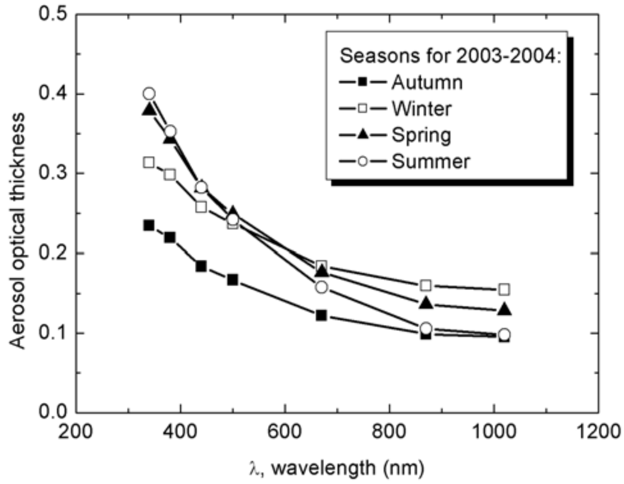

Figure 3. Seasonal variation of the spectral aerosol optical thickness $<\tau_{a,\lambda}>$ for cloud free atmosphere retrieved from direct sun measurements at the Kishinev site for 2003-2004.

Measurements of the total column ozone content in atmosphere are regularly made at the Kishinev site. Primarily, such measurements are fulfilled during the midday hours for cloud free atmosphere or in other time, depending on cloudy conditions. Results of measurements of the total column ozone content for September 2003-August 2004 at the Kishinev site, made with the hand-held MICROTOPS II Ozonemeter, are shown in Figure 4.

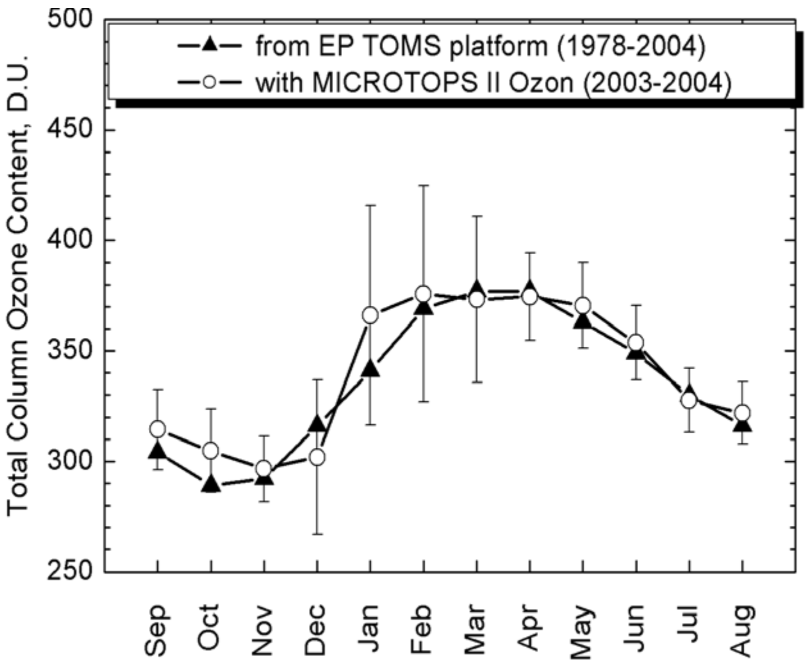

Figure 4. Monthly mean of total column ozone content measured with MICROTOPS II Ozonemeter at the Kishinev site for 2003-2004 and datasets retrieved from EP TOMS satellite platform for 1978-2004.

Monthly means of total column ozone are complimented with their standard deviations. Results of multi-annual statistics of monthly means of column ozone content over Moldova region for 1978-2004 are also shown in Figure 4. These data sets were retrieved from the Earth Probe (EP) Total Ozone Mapping Spectrometer (TOMS) satellite platform. From multi-annual statistics of monthly means it is clear seen the existence of minimum and maximum values which are peculiar to October-November and March-April months, respectively. Total ozone column measured with MICROTOPS at the Kishinev site for 2003-2004 reveals the same dependence. It should be noted that period of observation for December 2003-March 2004 may be characterized as a period with high variability of the total column ozone content. For the period of observation September 2003- August 2004 minimum and maximum values of total column ozone content measured at the Kishinev site were ~271 D.U. (on December 4, 2003) and 489 D.U. (on February 12, 2004), respectively. The analogous values retrieved from the EP TOMS multi-annual (for 1978-2004) statistics are ~203 D.U. (on December 1, 1999) and ~532 D.U. (on March 3, 1988). Extremely low value of total column ozone registered in our latitude by EP TOMS satellite platform was due to formation of the ozone mini holes over the Moldova.

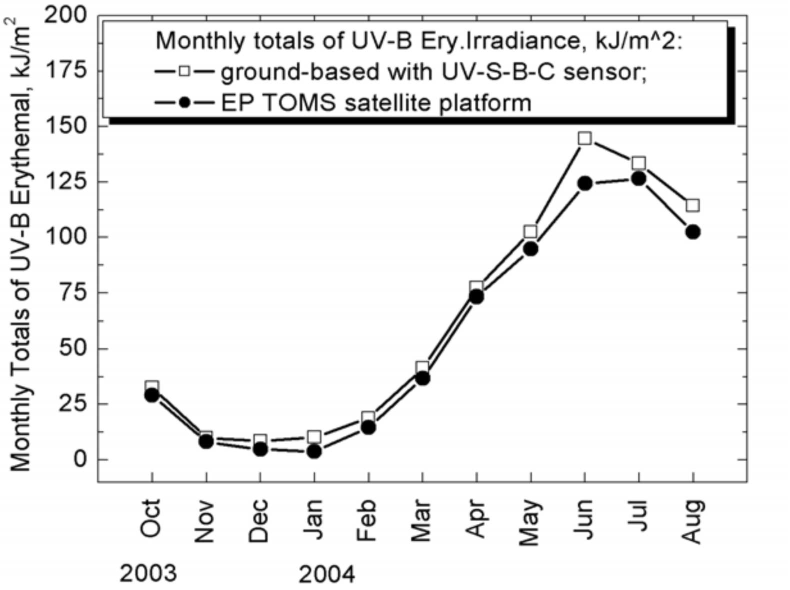

Figure 5. Monthly totals of solar UV-B erythemal global irradiance measured at the Kishinev site and UV-B erythemal global irradiance retrieved from satellite platform EP TOMS for 2003-2004.

Figure 5 illustrates the monthly totals of solar UV-B erythemal global irradiance on horizontal plane measured at the Kishinev site with UV-B-S-C sensor (bandwidth of 280-315 nm) and retrieved from the EP TOMS platform for October 2003- August 2004. It is clearly seen the existence of the minimum (for December) and maximum (for June) of measured solar UV erythemal global radiation. This minimum was due to low height of the Sun above the horizon during the month of December (with short period of daylight). Maximum value of monthly totals of UV erythemal irradiance corresponds to June (with long period of daylight). Data measured with the UV-B-S-C sensor at the Kishinev site are in a good agreement with those ones retrieved from the EP TOMS platform.

Diurnal variation of the solar UV-B erythemal global and diffuse irradiance on horizontal plane measured at the Kishinev site for the July 21, 2004 (clear cloud free day) is shown in Figure 6. Measurements were made with two UV-S-B-C sensors (open and shaded dome) with 1-sec resolution and 1-minute averaging interval. Maximum of UV-B erythemal global irradiance was ~ 0.233 W/m^2 at local noon. Daily mean AOT $<\tau_a(500)>$ was ~ 0.18 and total column ozone was ~ 319 D.U. on July 21, 2004.

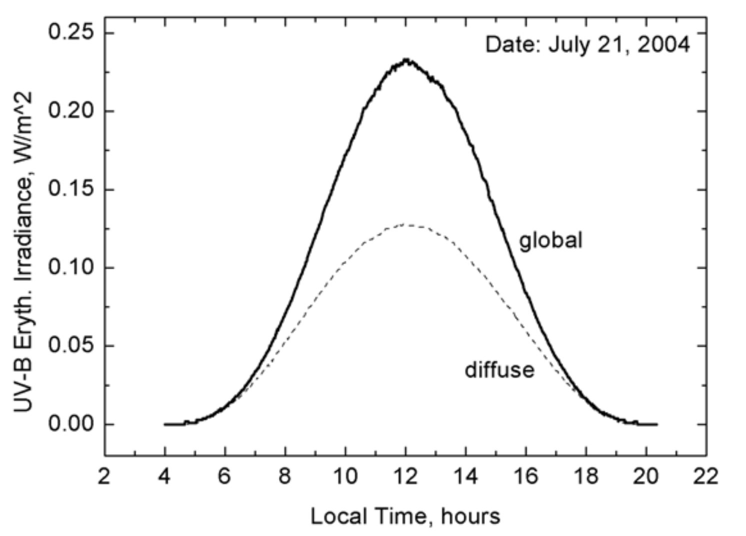

Figure 6. Diurnal variation of solar UV-B erythemal global and diffuse irradiance on horizontal plane measured at the Kishinev site for the July 21, 2004.

The maximum value of the UV-B erythemal global irradiance ever measured for the period of observation from October 2003 to August 2004 at the Kishinev site was ~ 0.268W/m^2 at local noon (on June 23, 2004). Daily mean of <τ_a(500)> was ~0.098 and total column ozone was ~334 D.U. during the observation day.

Datasets with the solar UV-B erythemal global and diffuse irradiance on horizontal plane measured at the Kishinev site are processed taking into account for each UV-S-B-C sensor individual tables with the adjustment factors. The parameters required for the correction of the radiometer output are total ozone column content and solar zenith angle at the time of the measurement. Solar UV-B erythemal global and diffuse irradiance and total column ozone content are submitted to the World Ozone and Ultraviolet Radiation Data Centre (WOUDC), Toronto, Canada.

Conclusions

Column-integrated aerosol optical and microphysical properties were retrieved from the measurements made with sunphotometer at the Kishinev site in frames of the AERONET program. One year (2003-2004) monthly average values of AOT reveal the resemblance with multi-year statistics of monthly mean AOT retrieved at the Kishinev site for 1999-2004. The most variation of AOT values was common to January-March and May for 2003-2004. Seasonal variation of AOT features clear spectral dependence in wavelength range from 340 nm to 1020 nm.

For the first time in Moldova it was developed and established a ground-based multifunctional radiometric complex. This complex is intended to carry out long-term continuous monitoring of radiative properties of atmosphere and solar radiation, and to acquire datasets of the broadband measurements of solar radiation (global, diffuse and direct components) from UV-B to IR. The complex is placed in an urban environment at the Kishinev site. At this site of observations regular measurements of the total column ozone content are made since the July, 2003. Solar and atmospheric radiation measurements in a wide spectral wavelength region are under way since the October, 2003. Original results of observation and photos of the radiometric complex are presented.

It was shown the existence of minimum and maximum values of total column ozone which are peculiar to October-November and March-April months, respectively, for 2003-2004 period of observation and this seasonal variation is in a good agreement with the multi-annual statistics of monthly means of column ozone retrieved from the EP TOMS platform for 1978-2004. High variability of the total column ozone content was registered for December 2003-March 2004. For the period of observation September 2003- August 2004 minimum and maximum values of total column ozone content measured at the Kishinev site were ~271 D.U. (on December 4, 2003) and 489 D.U. (on February 12, 2004), respectively. Monthly totals of solar UV-B erythemal global and diffuse irradiance measured at the Kishinev site reveal the existence of the minimum (for December) and maximum (for June) values.

Final data for solar and atmospheric radiation measurements, UV-B erythemal irradiance, and total column ozone content are of high quality and accuracy in accordance with the WMO requirements and demands adopted at the Baseline Surface Radiation Network (BSRN) station and WOUDC.

Acknowledgements

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References

1. Holben B.N. et al., (1998), *Rem. Sens. Environ.,* v. 66, 1-16.
2. Eck, T.F., et al., (1999), *J. Geophys. Res*., v.104, 31333-31350.
3. Smirnov A., Holben B.N., Eck T.F., Dubovik O., and Slutsker I., (2000), *Rem. Sens. Env*., v.73, 337-349
4. Dubovik, O. and King M. D., (2000), *J. Geophys. Res.*, v.105, 20673-20696.
5. Dubovik, O., et al. (2000), *J. Geophys. Res*., v.105, 9791-9806.
6. Morys, M., et al., (2001), *J. Geophys. Res.,* v.106, 14573-14582.