SOLAR RADIATION OBSERVATIONS AT THE GROUND-BASED RADIATION MONITORING COMPLEX IN REP. of MOLDOVA

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Abstract

Description of the ground-based solar radiation monitoring complex is presented. Complex comprises a set of the state-of-the-art solar radiation sensors, automatic sun-tracking unit and electronics, sunphotometer, portable hand-held ozonometer, and automatic weather station. Total ozone content in column of atmosphere, solar broadband irradiances from UV-B to the far IR, spectral aerosol optical thickness (AOT), retrieved column integrated aerosol optical and microphysical characteristics, and main surface meteorological elements are measured at this ground station. AOT observations are fulfilled within the frame of the global Aerosol Robotic Network (AERONET) program under supervision of the NASA Goddard Space Flight Center. Radiometric and ozone data are submitted to the World Radiation Data Centre (WRDC) and World Ozone and Ultraviolet Radiation Data Centre (WOUDC). Some preliminary results of AOT, shortwave solar radiation, total ozone content, and main meteorological elements acquired at the ground based solar radiation monitoring station are presented.

Keywords: solar radiation, optical thickness, column ozone content

Equipment and Measurements

In September 2003, for the first time in Rep. of Moldova it was developed and established a modern ground-based multifunctional solar radiation monitoring complex (Aculinin et.al., 2004a). The complex was placed in an urban environment at the Kishinev site (see Fig. 1) with coordinates: $\varphi=47.0013^0$N, $\lambda_o= 28.8156^0$E, h=205 m a.s.l. All instrumentation was mounted on the roof of the building of the Institute of Applied Physics, Academy of Sciences of Moldova. Complex comprises a set of the state-of-the-art solar radiation sensors, data logger CR10X-4M and automatic solar tracker unit 2AP BD (Kipp&Zonen). These instruments are assembled in two main sub-units (see Fig.1): moving platform (to measure diffuse and direct components of solar radiation) and stationary platform (to measure global component of solar radiation). This complex is used for long-term continuous monitoring of solar broadband irradiance at the Earth's surface in a wide wavelength bands from UV to IR. Sample rate and interval of averaging were selected as 1 sec and 1 minute, respectively, for each of the sensor. Data sets stored in memory module SM4M are regularly transferred to the remote PC located in Laboratory. Total flow of

raw data averaged for 1-minute interval and hourly totals from all solar sensors amounts to 6 Mb/month.

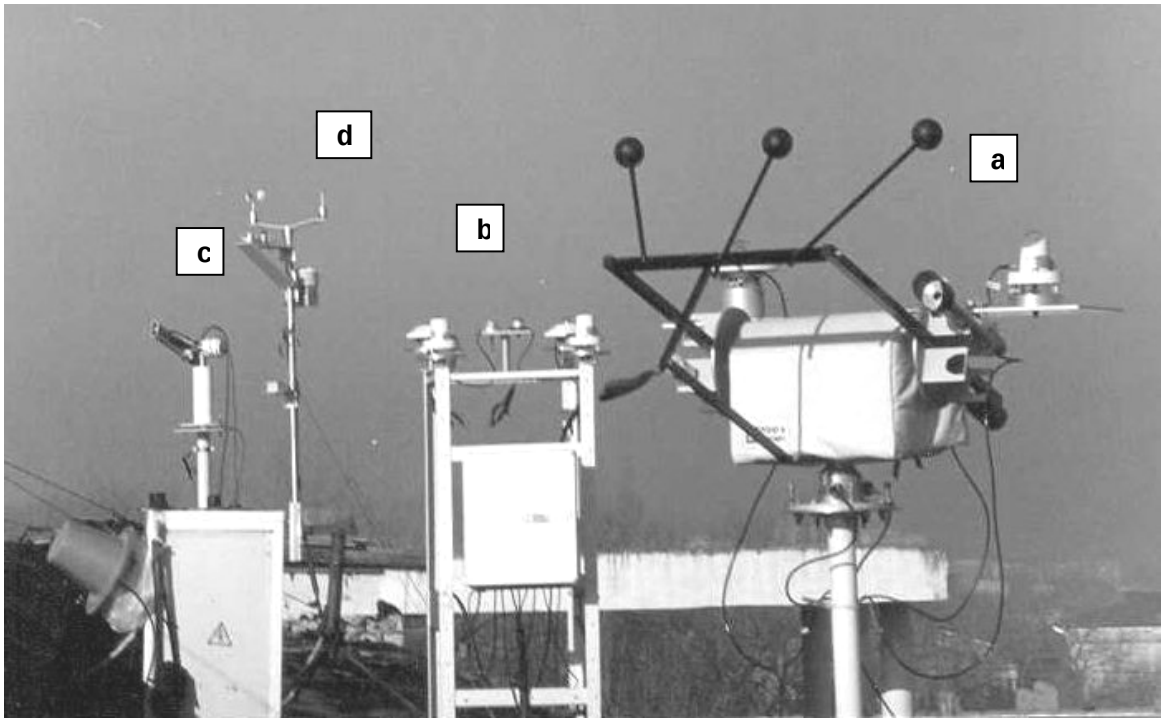

Figure 1. Ground-based solar radiation monitoring station in operation at the Kishinev site. Solar monitoring station consists of radiometric complex with moving (a) and stationary (b) platforms, sunphotometer Cimel-318 (c) and automatic weather station MiniMet (d).

The set of solar radiation sensors in use at the solar radiometric complex, description of measured values and broadband wavelength ranges are presented in Table 1. Solar radiation sensors are of the Secondary Standard and First Class. Radiometric complex is currently used to carry out continuous and simultaneous measurements of diffuse, direct and global components of shortwave solar radiation and global longwave atmospheric radiation. A set of sensors UV-S-B-C, CM-11 and CH-1 is utilized to make measurements of diffuse and direct components of shortwave solar radiation. These sensors are placed on the moving platform from the automatic solar tracking unit 2AP BD.

Table 1. Solar radiation sensors used in ground solar radiometric complex

Type of sensor	Measured components	Radiation	wavelength range
UV-S-B-C	diffuse, global	UV-B radiation	280 - 315 nm
UV-S-A-C	global	UV-A radiation	315 - 400 nm
PAR Lite	global	Photosynthetically active radiation	400 - 700 nm
SP Lite	global	Visible and near infrared radiation	400 - 1100 nm
CM-11	diffuse, global	Solar radiation	305 - 2800 nm
CH-1	direct	Solar radiation	200 - 4000 nm
CG-1	global	Atmospheric (longwave) radiation	4,5 - 42 μm

Another set of sensors is mounted on the stationary platform placed at a distance of 6 meters apart from the moving platform. These sensors are used to carry out measurements of global downwelling components of solar and atmospheric radiation.

Results of observations

Below is presented only a small part of data acquired at the ground-station since the beginning of operation. Time series of monthly totals of global and diffuse components of shortwave solar radiation on horizontal plane is shown in Figure 2. It is clear seen the seasonal variation with maximum in summer and minimum in winter.

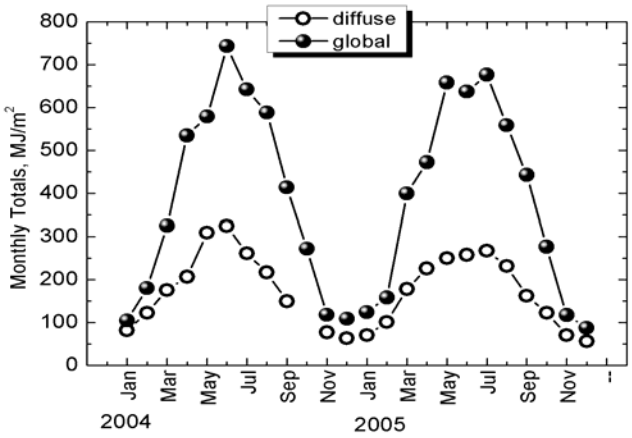

Figure 2. Time series of the monthly totals of the global and diffuse solar radiation (CM11 sensor, 305-2800 nm) on horizontal plane measured at the Kishinev ground-based solar radiation monitoring complex during 2004-2005.

Diurnal variation of global and diffuse components of solar radiation on horizontal plane for cloud free and cloudy days is shown in Figure 3a and 3b, respectively. Time series of the monthly totals of the global solar UV-B erythemally weighted and UV-A radiation on horizontal plane measured at the Kishinev for the period from 2004 to 2005 are shown in Figures 4 and 5.

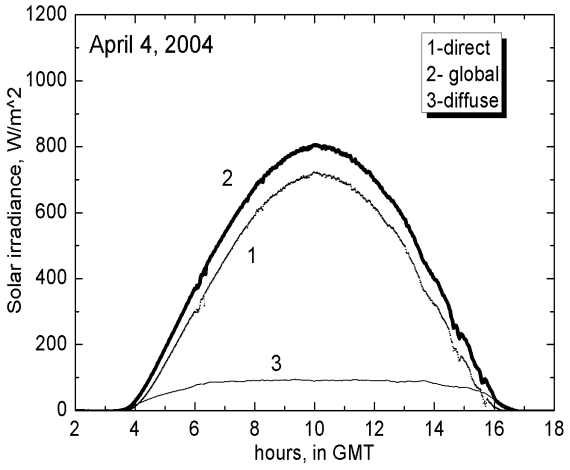

Figure 3a. Diurnal variation of the direct (1), global (2) and diffuse (3) components of the solar radiation on horizontal plane measured at the Kishinev ground station during April 4, 2004 (cloud free day).

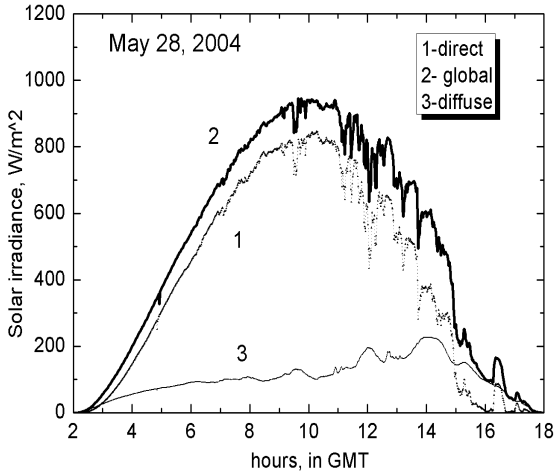

Figure 3b. Diurnal variation of the direct (1), global (2) and diffuse (3) components of the solar radiation on horizontal plane measured at the Kishinev ground station during May 28, 2004 (partially cloudy day).

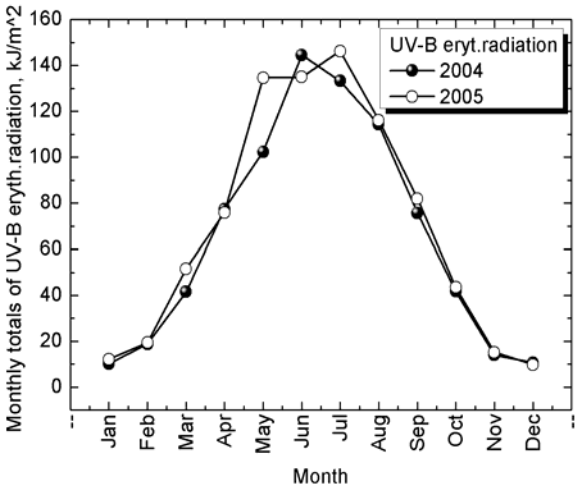

Figure 4. Time series of the monthly totals of the global solar UV-B erythemal radiation on horizontal plane measured at the Kishinev during 2004-2005.

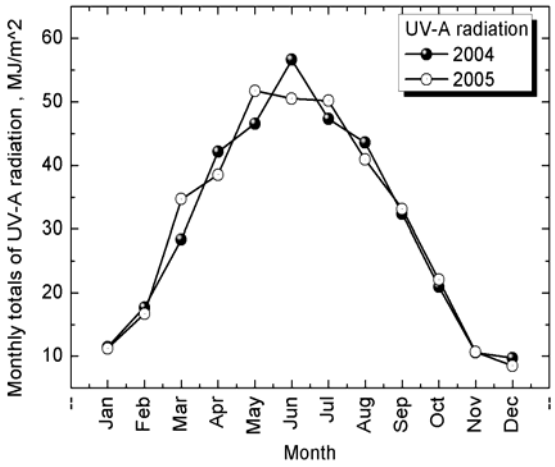

Figure 5. Time series of the monthly totals of the global solar UV-A radiation on horizontal plane measured at the Kishinev during 2004-2005.

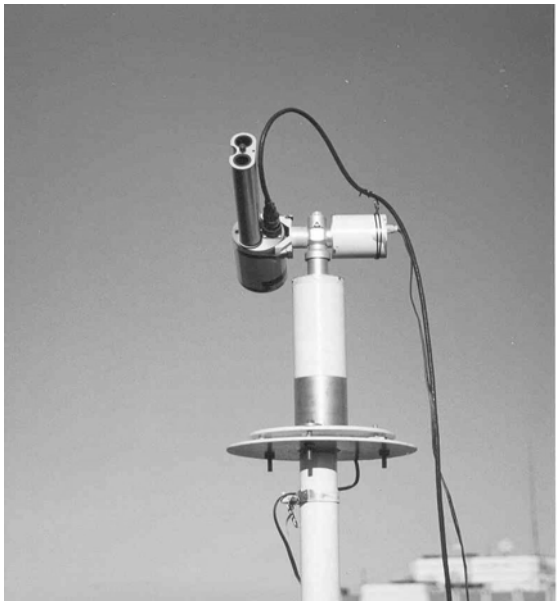

Figure 6. Sunphotometer CIMEL 318 in operation at the Kishinev site (within the framework of the AERONET program).

Since 1999, Moldovan research group has been using sunphotometer Cimel CE-318 (see Fig. 6) in their research activity and carrying out regular measurements of the direct sun radiance at 7 wavelengths in visible spectrum from 340 to 1020 nm, sky radiance in almucantar and in solar principal plane at 4 wavelengths from 440 to 1020 nm (Aculinin et.al. 2004b;c). These data are used to retrieve the columnar integrated optical and microphysical properties of atmospheric aerosols such as spectral aerosol optical thickness (see Figures 7 an 8), Angstrom exponent (as a parameter of spectral dependence of the aerosol optical depth), volume size distributions, complex refractive index of particulate matter, and single scattering albedo (Holben et.al. 1998; 2001). This sunphotometer is in operation within the framework of the global international Aerosol Robotic Network (AERONET) program under supervision of the NASA/GSFC (http://aeronet.gsfc.nasa.gov).

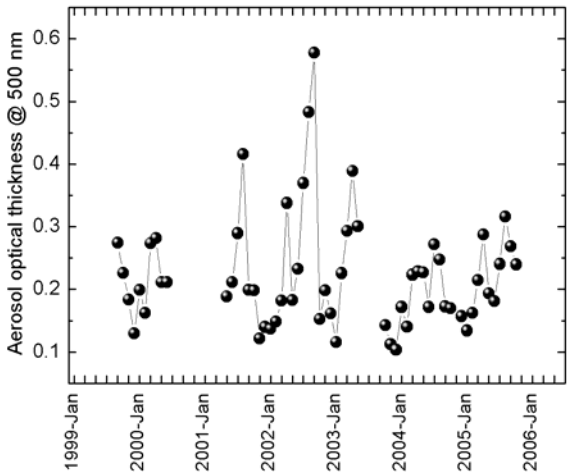

Figure 7. Time series of monthly mean values of the aerosol optical thickness at 500 nm observed at the Kishinev site during September 1999-December 2005.

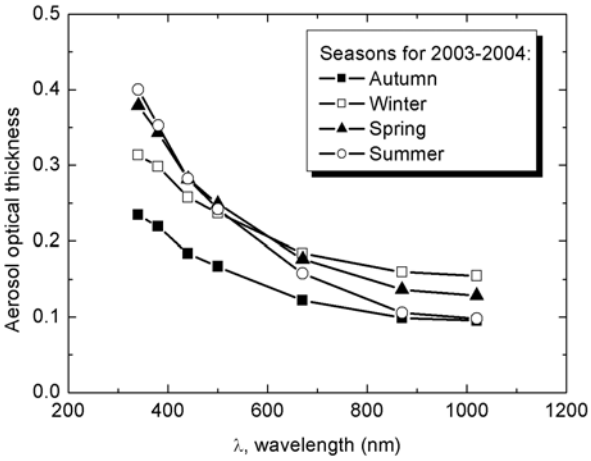

Figure 8. Seasonal variation of the spectral aerosol optical thickness for cloud free atmosphere retrieved from direct sun measurements at the Kishinev site during period from 2003 to 2004 .

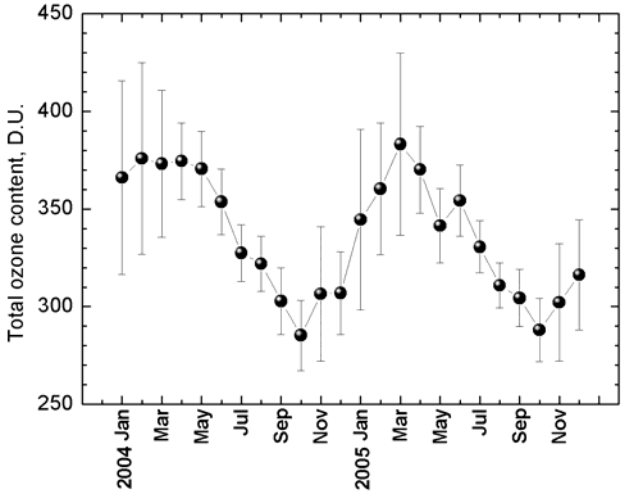

Figure 9. Time series of the monthly mean values of total ozone content measured with MICROTOPS II ozonometer at the Kishinev site from 2003 to 2004.

Measurements of the total ozone content (TOC) in the column of atmosphere are made on a regular basis at the Kishinev site (Aculinin A. , Smicov V. 2006; Aculinin A. 2006). The measurements are carried out with the hand-held ozonemeter MICROTOPS II Ozonemeter, Solar Light Co. This instrument is equipped with the highest grade and long stability filters (with ion-beam assisted deposition) at λ= 305, 312, 320, 936 & 1020 nm, which embedded into a solid cast aluminum housing to assure accurate and stable optical alignment. MICROTOPS II Ozonemeter has a low noise electronics and 20 bit A/D converter to give an accuracy (< 2% for ozone) comparable to much larger and more expensive instruments such as Brewer and Dobson spectrophotometers. MICROTOPS II is a hand-held device for

Figure 10. Automatic meteorological station MiniMet in operation at the Kishinev site

simultaneous measurements of direct solar ultraviolet radiation at 3 discrete wavelengths within UV-B range and TOC, accurately and dependably, and also for measuring total water vapor at fixed channel with 936 nm and aerosol optical thickness at 1020 nm. Variability of the monthly mean values of total ozone content measured with MICROTOPS II ozonometer at the Kishinev site during period from 2004 to 2005 are shown in Figure 9.

Radiometric data are supplied with the main meteorological elements such as air temperature, relative humidity of air, atmospheric pressure, wind mean velocity and direction, and solar irradiance in spectral wavelength ranges 280-315 nm and 400-1100 nm. Main meteorological elements are obtained from the automatic weather station MiniMet, Skye Instruments, Ltd., U.K. The system has seven active channels connected with the meteorological sensors. Each channel can be individually configured from the remote PC. Sample rate and interval of averaging were selected as 10 sec and 5 minute, respectively. Data acquiring, preliminary processing and store is fulfilled by data logger DataHog2. The overall raw data flow consists of 1.5 Mb/month. Automatic weather station MiniMet is arranged at a distance of 30 meters apart from the solar radiation measuring complex. Meteorological observations carried out at the ground station during 2004-2005 are presented below (see Figure 11 and 12).

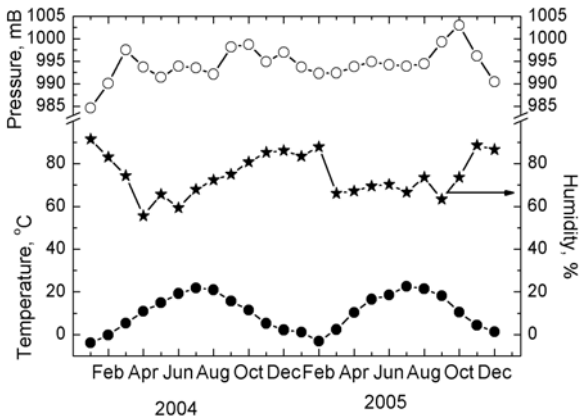

Figure 11. Time series of monthly mean values of the air temperature and pressure, and relative humidity observed at the ground station during 2004-2005.

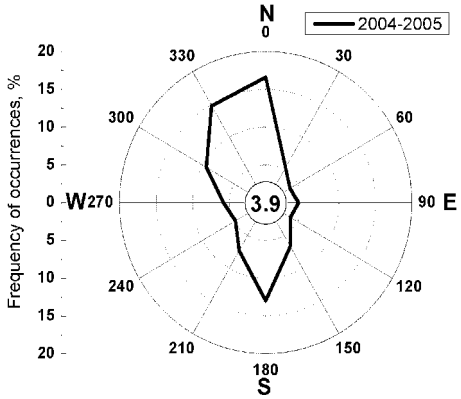

Figure 12. Combined wind rose observed at the ground station during 2004-2005. Frequency of occurrence of calm episodes is shown in the center of figure.

Output products from the long-term continuous observations made at the ground based solar radiation monitoring station are submitted to the AERONET and SolRad-Net databases, managed by NASA/GSFC, to the WMO World Data Centers such as World Ozone and Ultraviolet Radiation Data Centre (WOUDC), Toronto, Canada and World Radiation Data Centre (WRDC), St. Petersburg, Russia. Solar radiation monitoring station in Kishinev was registered in Global Atmosphere Watch Station Information System (GAW SIS) as a Regional fixed station in WMO RA VI – Europe managed by Swiss Federal Laboratories for Materials Testing and Research (EMPA), Dübendorf, Switzerland.

Conclusions

Solar radiometric complex at the Kishinev site gives the opportunity to carry out continuous measurements of broadband solar radiation in spectral sub-intervals ranged from UV through near IR and longwave atmospheric radiation in urban environment. Spectral AOT values are measured with sunphotometer Cimel CE-318 within the framework of global AERONET program to study aerosol optical properties and their temporal variation. Total column ozone content is regularly measured with the hand-held ozonometer. Main surface meteorological elements measured at the ground station at the Kishinev site supplement solar radiation data.

Acknowledgements

The work was funded in part by the U.S. Civilian Research &Development Foundation (CRDF) and the Moldovan Research and Development Association (MRDA) through grant #ME2-3033.

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