GROUND-BASED MULTIFUNCTIONAL RADIOMETRIC COMPLEX FOR ATMOSPHERIC AND SOLAR RADIATION MEASUREMENTS AT THE KISHINEV SITE, MOLDOVA

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Abstract

The information about the ground-based multifunctional radiometric complex is presented. Radiometric complex is designated to make a high quality long-term continuous monitoring of the solar and atmospheric radiation and to collect datasets with the solar radiation broadband measurements from UV-B to IR. Complex is placed in an urban environment at the Kishinev site. Solar radiation data are supplied with the main meteorological elements such as air temperature, relative humidity, atmospheric pressure, wind mean velocity and direction, and solar irradiances, which are continuously measured with the automatic meteorological station. Measurements of the total column ozone content with the MICROTOPS II Ozonemeter are regularly fulfilled at the Kishinev site. Results of measurements of the solar and atmospheric radiation and total ozone content in the column of atmosphere are originally presented for the Kishinev site of observation.

1. 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 exert an essential influence on atmosphere of the Earth modifying its structure, properties and components. The main components of such complex system as atmosphere are gases and aerosol particles, respectively. Solar radiation reaching our atmosphere interacts with each component in too involved forms and finally resulting in absorbing and scattering of radiation. Each of components has a specific influence upon the radiation exchange and interaction processes. Ground-based solar radiation monitoring networks of stations [1-3] are of a particular interest to obtain an exhaustive and reliable continuous flow of information about the resulting radiation field on the earth surface. These stations are equipped with the state-of-the-art instrumentation such as solar radiation sensors for broadband measurements from the UV through the IR, with an active solar tracking units, with smart data loggers of high complexity and possibility to acquire, pre-process and store huge measured data arrays, and with the modern software for data treatment, quality control and analysis. Measurement techniques and data quality control procedures are to be full in accordance with the WMO requirements [1]. Meanwhile, the tasks of establishment of new modern solar radiation monitoring stations at new sites of observation in a worldwide and incorporating them into the respective network, are a great of interest both for regional, and global radiative forcing investigations. In this connection, creating any of new ground-based solar radiation station is essential and necessary action.

2. Radiometric complex and measurement approach

Firstly in Moldova it was developed ground-based multifunctional radiometric complex. This complex is intended to carry out long-term continuous monitoring of radiative properties of atmosphere and to acquire datasets with 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 (see Fig. 1) with coordinates: φ=47.0013^{0}N, λ=28.8156^{0}E, h=205 m a.s.l. Radiometric complex was mounted on the roof of the building of the Institute of Applied Physics, Academy of Sciences of Moldova.

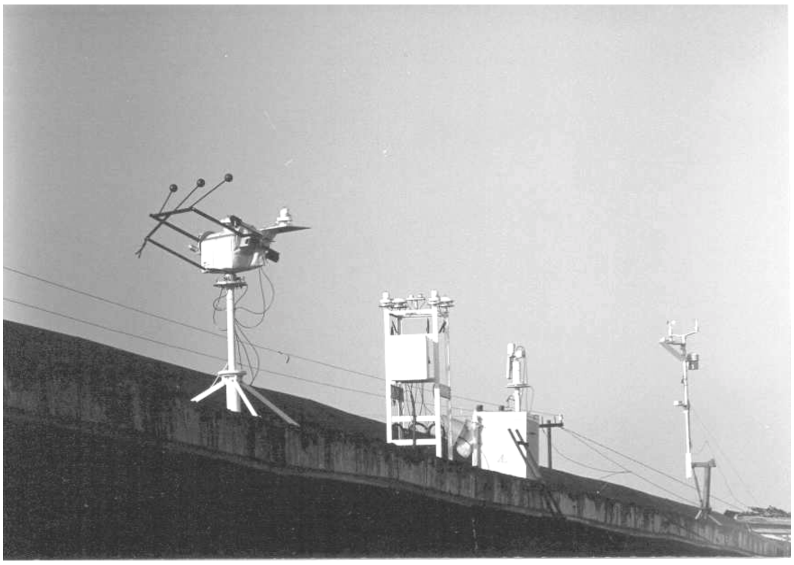

Fig. 1. Ground-based multifunctional radiometric complex

Automatic multifunctional complex for radiometric measurements has been developed and assembled from the separate parts such as electronics and mechanical units, and solar radiation sensors manufactured by worldwide known company Kipp &Zonen, The Netherlands. All sensors and separate elements which are assembled together into the radiometric measuring complex are in accordance with the ISO 9001 and World Meteorological Organization (WMO) standards [1] for application in atmospheric researches on the radiation and meteorological networks. The solar radiation sensors are of the Secondary Standard and First Class. The sensors are especially designed for long-term reliable measurements. They are robust and require a little maintenance. Radiometric instrumentation from Kipp&Zonen represents a backbone of the developed radiometric complex. Instrumentation is highly compatible with the data logger CR10X, which allows to obtain data with high quality and accuracy in measuring procedure. Multifunctional radiometric complex makes it possible to carry out the long-term continuous and simultaneous measurements of solar and atmospheric radiation in a wide spectral wavelength region ranged from the ultraviolet biologically active (UV-B) part of solar radiation through the infrared (IR) margin of atmospheric radiation spectrum. The main peculiarity of the complex is that such measurements can be simultaneously made in a separate broadband wavelength intervals, which are particularly overlapping with each other at their margins. Those selected wavelength bands are exactly attributed to the specific spectral characteristics of each solar radiation sensors (see. Table 1), assembled into the complex.

Table 1. Solar radiation sensors used in radiometric complex

Type of sensor	Measured components	Radiation	Spectral 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 (PAR)	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

Radiometric complex is currently used to carry out continuous and simultaneous measurements of diffuse, direct and global components of solar radiation (short wavelength) and global atmospheric radiation (long wavelength). A set of sensors UV-S-B-C, CM-11 and CH-1 is utilized to make measurements of direct and diffuse components of solar radiation. These sensors are placed on the moving platform from the automatic solar tacking unit 2AP BD (see. Fig. 2) which is designed for unattended normal incident direct and diffuse solar radiation measurements. Other 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 down welling component of solar and atmospheric radiation (see Fig. 3).

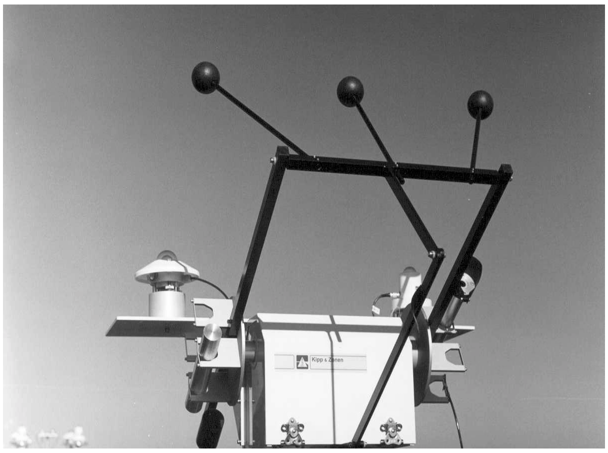

Fig. 2. Solar radiation sensors on moving platform

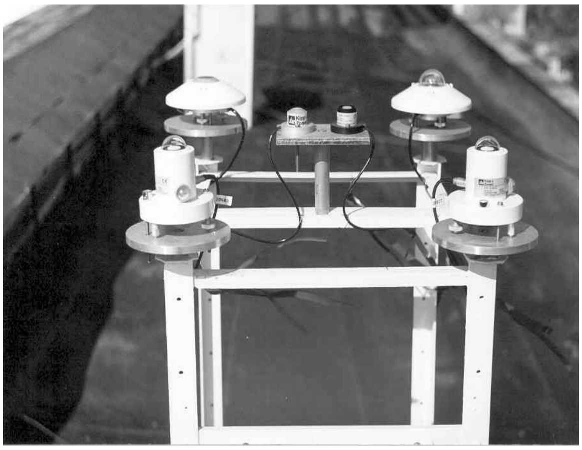

Fig. 3. Solar radiation sensors on stationary platform

Solar radiation sensors selection, their spectral characteristics and specifications, arrangement of sensors and platforms, selection of observation site, and solar radiation measurement techniques in different wavelength regions, were defined exactly in accordance with the WMO requirements [1], and guiding instructions which are adopted at the Global Atmospheric Watch (GAW) и Baseline Surface Radiation Network (BSRN) [2,3].

Data acquiring, pre-processing and their store are fulfilled with the data logger CR10X. Data logger has six differential adjustable input channels and battery backed internal memory module with the capacity of 128 kb. An analog input of each channel is adjusted giving the possibility to obtain signal resolution in the range from 0.33 to 333 μV depending on full scale input range. The instrument has precise 13 bits A/D converter of signals to assure of 0.1% accuracy. Channel expansion of the data logger CR10X is provided by AM25T Thermocouple multiplexer. Data logger CR10X is mounted on stationary platform and is connected with each solar radiation sensor through the AM25T thermocouple multiplexer with 32 channels. These sensors are placed at the distance of no more than 10 meters apart from the data logger CR10X to minimize the noise influence upon the signals from sensors. Differential channels from CR10X and AM25T are only used to reach a high accuracy of measurements of signals from the solar sensors. It is only used nine differential channels connected with the respective sensors. Sample rate and interval of averaging were selected as 1 sec and 1 minute, respectively. Data sets stored in memory module SM4M with the capacity of 4Mb are regularly transferred to the remote PC located in Laboratory. The distance between the data logger and PC consists of 20 meters. Raw data flow averaged for 1-minute interval and hourly totals from each solar sensor amounts of 4-6 Mb/month. To provide back up during the signal measurements and data storing in case of power failure, data logger is equipped with the rechargeable 12V battery, charged with AC power. Voltage transformer 220V/12V which runs off mains power is mainly used to provide a 12V DC to the data logger CR10X.

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. Data acquiring, preliminary processing and store is fulfilled by data logger DataHog2. Data logger is connected with every sensor from weather station and it is placed in outdoor environment and mounted at the mast. The system has seven active channels connected with the meteorological sensors. Each channel can be individually configured from the remote PC: the user may at any time reconfigure the channels and sampling/averaging intervals. Sample rate and interval of averaging were selected as 10 sec and 5 minute, respectively. Data sets are stored in data logger DataHog2 lithium battery backed memory module with the capacity of 128 kb. Pre-processed and averaged data from data logger are readout by remote PC placed in Laboratory. For using of 5-minute averaging interval, 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 radiometric measuring complex. The position of station was selected in such a manner that solar radiation sensors from the radiometric complex were unaffected by shadowing from the weather station. ACC/9 Mains Hog is used as voltage transformer (220V/12V), which runs off mains power and provides 12V dc supply to the data logger DataHog 2. To guarantee continuous mode of measurements in case of power failure, weather station is equipped with the internal autonomous system of power supply from the alkaline batteries 'C'-type.

Measurements of the total ozone content (TOC) are made on a regular basis at the Kishinev site. The measurements are carried out with the hand-held ozonemeter MICROTOPS II Ozonemeter [4], Solar Light Co. This instrument, 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 low noise electronics and 20 bit A/D converter to give an accuracy (< 2% for ozone) comparable to much larger and more expensive instruments; it has non-volatile memory and can be connected directly to the PC through the RS232 port for data transfer. MICROTOPS II is a hand-held device for 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. Due to portability, mobility and possibility to make quick (~ 10 - 30 sec, depending on the length of scan) measurements of the total ozone, the ozonemeter can be successfully used for measurements in conditions of broken clouds. Principally, the measurements of the TOC are carried out in solar culmination (in midday hours) with the small values of air mass or during the hours with an appropriate weather conditions (e.g., the presence of broken clouds). MICROTOPS II Ozonemeter allows to make reliable measurements of the TOC for air masses up to m= 3–3,5 (AM and PM). For days of observation with the typical high transparency and stability of atmosphere, measurements of direct solar UV radiation are fulfilled at three fixed channels with 305, 312 and 320 nm. Sample rate was ranged from 5 to 10 minutes. The data obtained are exploited for calibration and stability check of the ozonemeter on the basis of Langley technique.

2. Results of measurements

Some original results concerning the measurements of the TOC in column of atmosphere and solar and atmospheric radiation made at the Kishinev site are presented. Continuous measurements of the meteorological elements such as air temperature, relative humidity, atmospheric pressure, wind mean velocity and direction, and solar irradiance in wide spectral bands 280 - 315 nm and 400 - 1100 nm, have been making with automatic weather station since June 17, 2003. Regular measurements of the TOC have been carrying out with hand-held II Ozonemeter since July 7, 2003. Continuous measurements of the solar and atmospheric radiation in wide wavelength region ranged from UV-B through the IR in separate wavelength subintervals have been carrying out with multifunctional radiometric complex since September, 2003.

Results of measurements of the TOC in column of atmosphere and diffuse and global components of the solar UV-B erythemal radiation are regularly filled into the database of the World Ozone and Ultraviolet Data Centre (WOUDC). Results of measurements of the diffuse, direct and global components of the solar radiation for wavelength region of 305 - 2800 nm, and global component of the atmospheric radiation for wavelength region of 4,5 – 42 μm are regularly filled into the database of the World Radiation Data Centre (WRDC).

2.1 Measurements of total ozone content in column of atmosphere

Measurements of the TOC in atmosphere are regularly made at the Kishinev site. Primarily, such measurements are fulfilled during the midday hours or in other time, depending on cloudy conditions. Results of measurements of the total ozone content for the period of observation October-December 2003, made with the hand-held MICROTOPS II Ozonemeter, are shown in Fig. 5. Columnar ozone content decrease is typical for that selected period of observation in northern hemisphere. Monthly mean values of the TOC are presented in Table 2. These values clearly indicate the presence of tendency of the seasonal variation of the TOC in atmosphere. At the same time, some anomalous high values of the ozone content are observed. Thus, on December 7, 2003 the TOC in atmosphere, reached the value of 411 D.U.

Table 2. Total ozone content (D.U.) in atmosphere, measured with the MICROTOPS II Ozonemeter at the Kishinev site (observation period: July –December, 2003).

July	August	September	October	November	December
344	331	314	305	297	302

Data on TOC retrieved from the satellite platform the Earth Probe Total Ozone Mapping Spectrometry (EP TOMS) (see http://jwocky.gsfc.nasa.gov) are also shown in Fig. 5 for comparison with the results obtained at the Kishinev site. The high correlation between the EP TOMS and MICROTOPS II Ozonemeter results is readily seen from Fig. 5. But at the same time, there is a constant bias between these data sets: readings from MICROTOPS II Ozonemeter are above the analogous ones retrieved from the EP TOMS. Mean value of such bias amounts of 9 D.U. for that period of observation.

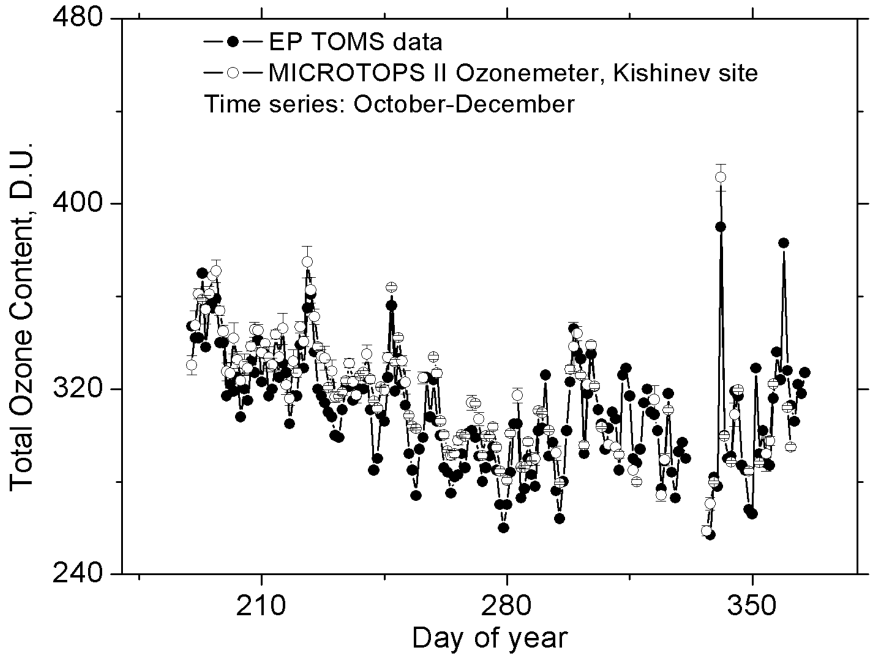

Fig. 5. Comparison of variation of the total ozone content in column of atmosphere at the Kishinev site along with the data retrieved from EP TOMS. Period of observation: October - December, 2003.

Variation of the TOC in atmosphere and global component of solar UV-B erythemal radiation for observation period of December 2003 are shown in Fig. 6. Measurements of the TOC and global erythemal radiation were made simultaneously and during the noon hours. As it can see from Fig. 6, there is a clear dependence between these readings: correlation coefficient R amounts of -0.881 .

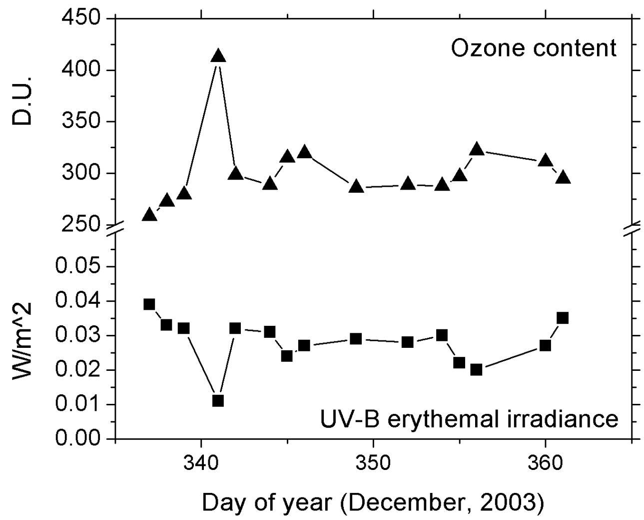

Fig. 6. Dependence of the total ozone content in column of atmosphere and global solar UV-B erythemal radiation at the Kishinev site. Period of observation: December, 2003.

2.2 Solar and atmospheric radiation measurements

Results of measurements of the monthly totals of global Q_{UVB} and diffuse D_{UVB} components of solar UV-B erythemal radiation and global Q_{UVA} component of the solar UV-A radiation on horizontal plane are presented in Table 3. Period of observation was chosen as October – December, 2003. It was shown the existence of the minimum for all measured components of solar UV radiation. This minimum was due to low height of the Sun above the horizon during the month of December.

Table 3. Monthly totals of the solar global Q_{UVB} and diffuse D_{UVB} components of the UV-B erythemal radiation, (wavelength range: 280-315 nm) and global UV-A radiation Q_{UVA}, (wavelength range: 315 - 400 nm) on horizontal plane.

	October, 2003	November, 2003	December, 2003	January, 2004
Q_{UVB} (global UV-B radiation), кJ/m^2	38.40	11.54	9.65	11.48
D_{UVB} (diffuse UV-B radiation), кJ/m^2	31.56	9.61	7.54	9.73
Q_{UVA} (global UV-A radiation), MJ/m^2	19.63	7.90	7.18	11.07

Variation of hourly totals for global solar radiation $\Sigma_h Q$ in relative units (in per cent from the daily totals $\Sigma_d Q$) is shown in Fig. 7. The results are presented for the period of observation from October, 2003 to January, 2004. The shape of the curve for daily variation of solar irradiance depends on length of daylight: for wintry days the shape of the curve becomes narrow in the region of curve base and increases in absolute value for curve maximum (at noon hours). Daily variation of the direct, diffuse and global components of solar radiation measured during October 20, 2003 at the Kishinev site is shown in Fig. 8. Measurements were made with 1-minute averaging interval.

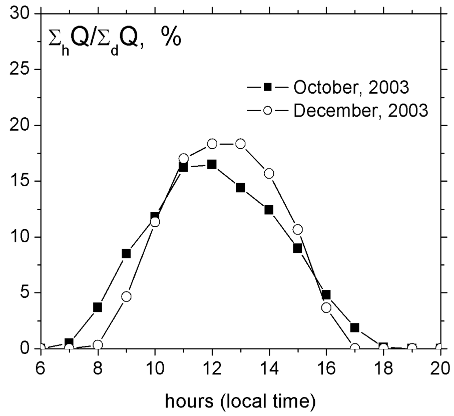

Fig. 7. Dependence of hourly totals of the global radiation $\Sigma_h Q$ (in % from the daily totals $\Sigma_d Q$).

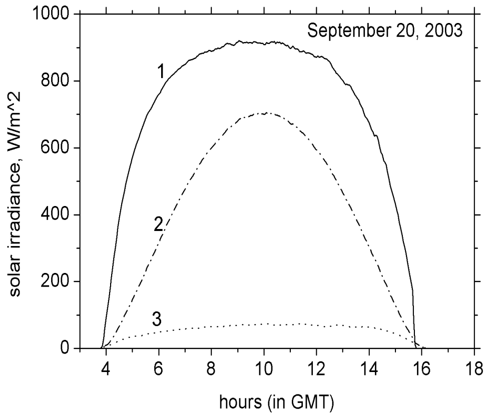

Fig. 8. Daily variation of the direct (1), global (2) and diffuse (3) components of the solar radiation on horizontal plane.

High transparency and stability of the atmosphere were distinctive for this selected day of observation. Results of aerosol optical thickness measurements for λ=1020 nm are presented in Table 4. During the morning hours in the direction of horizon it was observed light haze; in the course of midday there was observed a high transparency of the atmosphere, but for the afternoon hours the turbidity of atmosphere increased. Measurements of the direct solar UV radiation were carried out for fixed channels at λ= 305, 312 and 320 nm with the hand-held MICROTOPS II Ozonemeter and these results were used for Langley calibration of radiometer and for checking the stability of ozonemeter operation. Measurements have been made from 05:55 GMT (m=2.829 AM) through 14:08 GMT (m=3.010 PM) with 5-minute sampling interval.

Table 4. Aerosol optical thickness τ measured at a fixed channel λ= 1020 nm and respective air masses m.

Time(summer), GMT	05:55	07:59	09:51	12:00	14:08
τ(1020 nm)	0.039	0.028	0.017	0.029	0.067
m, air mass	2.829	1.640	1.433	1.657	3.010

Variation of global solar radiation (305–2800 nm) on horizontal plane for the period of observation from October, 2003 through January, 2004 is shown in Fig. 9. It is observed the seasonal decreasing of the measured solar irradiance. Minimum values of solar irradiance are reached in December.

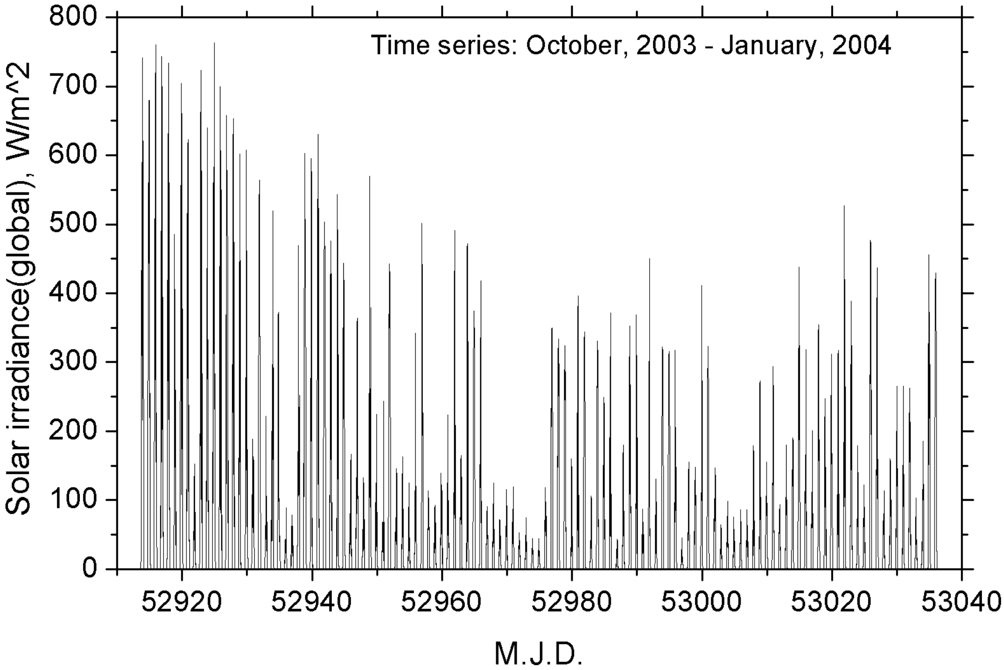

Fig. 9. Variation of the solar global radiation on horizontal plane. Observation period: October, 2003– January, 2004.

Monthly totals of global Q, diffuse D and direct S' components of solar radiation (wavelength range: 305 – 2800 nm) on horizontal plane are presented in Table 5. Again the monthly totals of photosynthetically active radiation Q_{PAR} (wavelength range: 400 - 700 nm) and monthly totals of global atmospheric longwave radiation Q_{IR} (wavelength range: 4.5 – 42 μm) are listed in this table.

Table 5. Monthly totals of the solar global Q, diffuse D and direct S' radiation on horizontal plane, (wavelength range: 305 - 2800 nm), solar global photosynthetically active radiation (PAR) Q_{PAR} on horizontal plane, (wavelength range: 400 - 700 nm); global atmospheric (longwave) radiation Q_{IR} on horizontal plane (wavelength range: 4.5 - 42 μm).

	October, 2003	November, 2003	December, 2003	January, 2004
Q (global radiation) , MJ/m^2	251.9	84.4	93.1	104.7
D (diffuse radiation), MJ/m^2	125.0	60.4	50.9	81.6
S' (direct radiation), MJ/m^2	124.0	24.8	42.5	23.2
Q_{PAR} (global radiation), mol/m^2	0.1596	0.0557	0.0590	0.0688
Q_{IR} (global radiation), MJ/m^2	773.4	795.2	720.7	708.2

3. Summary

Firstly 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 continuous measurements of meteorological elements have been carrying since June, 2003 and regular measurements of the total column ozone content are made since July, 2003. Solar and atmospheric radiation measurements in a wide spectral wavelength region are under way since October, 2003. Original results of observation and photos of the radiometric complex are presented. Final data for solar and atmospheric radiation measurements, total column ozone content are of high quality and accuracy in accordance with the WMO requirements and demands adopted at the BSRN station. This was reached due to exploiting the solar sensors of the First Class and Secondary Standard from the worldwide known company such as Kipp&Zonen, modern techniques for measurements and signal processing. The data obtained have high level of accuracy to be further used in computer modeling and analysis.

Acknowledgement

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