GROUND-BASED OBSERVATION OF SHORTWAVE SOLAR RADIATION DURING SOLAR ECLIPSE ON OCTOBER 3, 2005 IN CHISINAU, MOLDOVA

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Abstract

The influence of partial annular solar eclipse observed during October 3, 2005 onto the variation of shortwave downwelling solar irradiation at the Chisinau site is analyzed. Evaluation of the components of broadband solar radiation from UV-B to near IR falling onto the Earth's surface is presented. Such type of dimming was due to partial annular solar eclipse event with maximum phase of 40%, which resulted in 3.4- 4.5% reduction of daily totals of shortwave downwelling solar radiation.

1. Introduction

Solar eclipse represents the phenomenon of covering the solar disk by moon and as the case it may be characterized as full, annular or partial. Fraction of the surface of the solar disk obscured by the moon during solar eclipse is determined by the time and position given. That phenomenon occurs rather frequently. Every year from 2 to 5 of solar eclipses can be observed all around the world. In each specific place on the Earth's surface solar eclipses are observed on an average one time in few years. For example, there were observed 35 solar eclipses in Moldova of recent 100 years. All these eclipses were characterized as partial ones. The next solar eclipse which can be observed on the territory of Moldova will occur on March 29, 2005 and will be characterized as a partial eclipse. Maximum of solar disk obscuration will consist of 75%.

Solar eclipse represents an interest for investigation because during the solar eclipse there can be observed solar radiation flux decreasing, changing of the optical properties of the atmosphere(spectral transmittance, polarization properties, etc) and meteorological parameters [1-3]. Solar radiation remains the main measurable parameter affected by solar eclipse. The subject of this paper is to investigate variation of the broadband shortwave downwelling solar radiation in the spectral wavelength range from ultraviolet (UV) to near IR during the solar eclipse observed over Moldova on October 3, 2005.

2. Equipment and results of measurements

Since 2003 continuous measurements of broadband shortwave downwelling solar radiation from UV to IR have been carrying out at the ground based solar radiation monitoring station at the Institute of Applied Physics. The station consists of radiometric complex, automatic weather station, ozonometer, and sunphotometer Cimel-318. Radiometric complex is composed of the set of radiometric sensors from Kipp&Zonen such as CM-11 pyranometers, CH-1 pyrheliometer, Photosynthetically Active Radiation (PAR), UV-B and UV-A sensors to measure solar radiation [3]. Stability of optical properties of atmosphere

over the site was checked with collocated and synchronous measurements of spectral aerosol optical depths (AOD) with sunphotometer Cimel-318. Spectral AODs were measured with sunphotometer at seven wavelengths from 340 nm through 1020 nm. Measurements of AOD were fulfilled within the framework of the Aerosol Robotics Network (AERONET) programme, managed by NASA/GSFC [4].

Ordinary solar eclipse took place on October 3, 2005. Moon angular diameter was smaller than the solar one, so in zone of maximum phase the moon didn't obscure the solar disk completely. In Chisinau this solar eclipse was observed as partial annular eclipse with maximum obscuration of solar disk with 40%. Solar eclipse continued from 08:22:23 UTC to 10:46:55 UTC. The maximum of occultation was observed in Chisinau at 09:33:50 UTC.

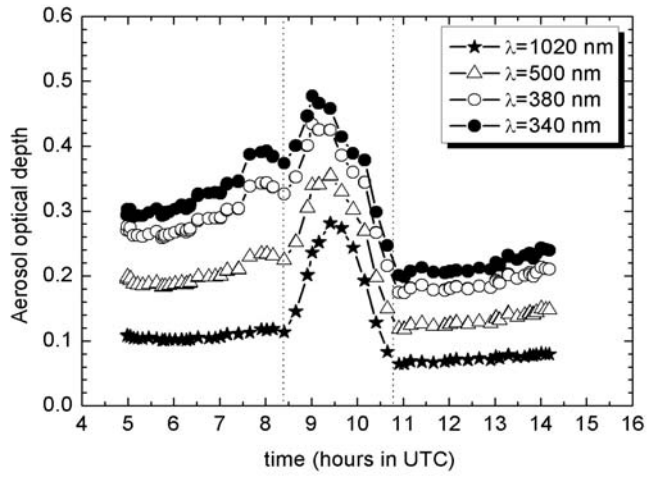
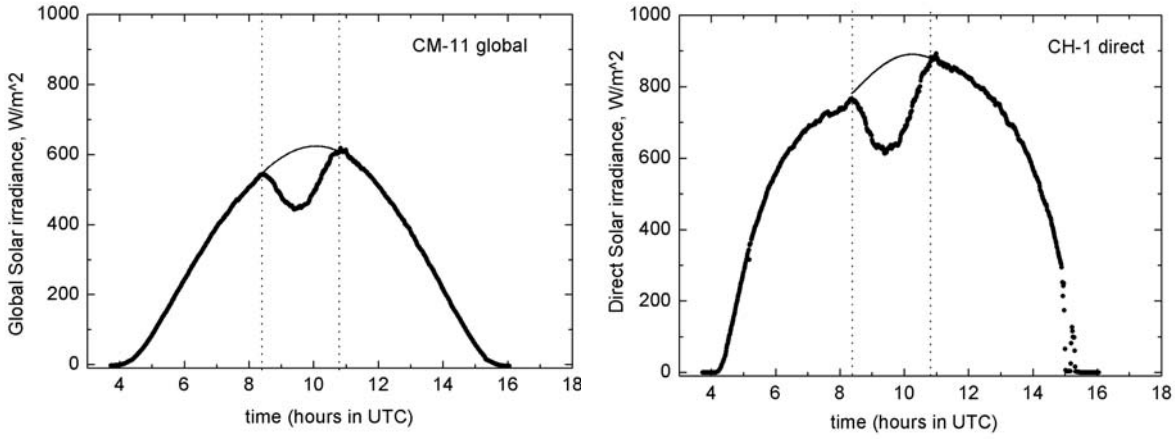


Figure 1. Diurnal variation of spectral AOD $\tau_a(\lambda)$ measured with sunphotometer Cimel-318 at the Chisinau site during solar eclipse event in October 3, 2005.

The overall meteorological conditions were good: cloudless sky with light haze during the whole day and the eclipse period. Diurnal variation of spectral aerosol optical depths $\tau_a(\lambda)$ measured with sunphotometer at selected wavelengths in the UV-visible-near IR range during partial annular solar eclipse is shown in Figure 1. Two vertical dotted lines show beginning and ending of solar eclipse. AODs $\tau_a(\lambda)$ show smooth variation both in the morning and afternoon hours, that confirms the fact of the stability of optical properties of the atmosphere during observation. Some clearance of the atmosphere was observed in the afternoon hours. Spectral aerosol optical depths $\tau_a(\lambda)$ measured in the morning hours are higher than analogous values obtained in the afternoon, i.e. AOD values $\tau_a(\lambda)$ measured at λ=500 nm and averaged over period of time before(in the morning) and after (in the afternoon) solar eclipse were $\langle\tau_a\rangle$ =0.20 and $\langle\tau_a\rangle$ =0.13, respectively. For comparison, climatological mean value of AOD $\langle\tau_a\rangle$ obtained at the Chisinau site over period of observation 1999-2004 equals 0.23 at λ=500 nm. The appearance of distinctive maximum in $\tau_a(\lambda)$ for each of wavelengths during the eclipse event is accounted for by the fact that AODs are deduced using the Langley calibration technique. This technique defines extra-atmospherical constants as input parameters for sunphotometer in the case of clear solar disk. In the case of solar eclipse these constants remain the same as initial ones obtained at the calibration facilities, but incoming solar radiation measured by sunphotometer at the Earth's surface is partially attenuated due to eclipse event only. The appearance of the above mentioned maxima in AOD's cannot be connected with the low transparency of atmosphere due to increase of aerosol loading or cloud effect. It must be considered as artifacts and AODs data collected during eclipse period should be eliminated from the final dataset.

Global components of shortwave downwelling solar radiation were measured with sensors mounted on the stationary platform. Direct and diffuse components of solar radiation were measured with set of sensors installed on moving platform of active sun-tracker 2AP BD. Radiometric data were collected with 1-minute averaging interval. This interval is well suited to observe the impact of transient solar eclipse on measured shortwave downward solar

radiation. Diurnal variation of global and direct components of solar radiation measured at Chisinau site during solar eclipse event on October 3, 2005 is shown in Figure 2 (a,b).



a. b.

Figure 2(a,b). Diurnal variation of global (a) and direct (b) components of shortwave downwelling solar radiation measured at Chisinau site during solar eclipse event on October 3, 2005. Vertical dotted lines correspond to the beginning and ending of eclipse. Thin curves show the expected variation of solar irradiance during eclipse.

It is clearly seen that obscuration of solar disk resulted in temporal dimming or reduction of solar radiation fluxes measured at the Earth's surface. From 08:22:23 UTC shortwave downward solar radiation began to decrease and at 09:33:50 UTC radiative flux reached the minimum. Then it began gradually to increase and at 10:46:55 UTC radiative flux returned to normal value. Appearance of the minimum on the curve, describing diurnal variation of any component of solar radiation, corresponds to the maximum of solar disk obscuration. The analogous variation is typical for diffuse component of solar radiation, UV-B and UV-A radiation, and PAR. Some asymmetry in the shape of curve describing diurnal variation of direct solar radiation (on perpendicular plane) is observed. This was due to the fact that spectral transparency $e^{-\tau(\lambda)}$ of atmosphere in the morning hours was lower than in the afternoon. Expected variation of solar irradiance during eclipse is marked by thin curves in Figure 2(a,b). These modeled relationships are used to evaluate influence of temporal dimming effect caused by solar eclipse. Values of contribution for each of components of broadband solar radiation are computed relatively to the maximum of the phase of solar eclipse, to the sums recorded during the period of eclipse and to the daily totals of solar radiation. Respective values of contribution are presented in Table 1.

Computed values of contributions from dimming effect due to partial annular solar eclipse relative to the maximum of the phase of solar eclipse and to the sums recorded during the period of eclipse ranged from 23.9% to 43.5% and from 12.2% to 20%, respectively. Diffuse component of shortwave solar radiation showed the deepest minimum ~43.5% among other components of solar radiation. This was owing to relative low transparency of the atmosphere with haze. Reduction of daily totals of solar radiation due to solar eclipse varied from 3.4% to 4.5%.

Table 1. The influence of partial solar eclipse onto the components of broadband solar radiation (from UV-B to near IR) falling on horizontal surface. Values of contribution for each of components are computed relative to respective estimated values of solar radiation.

Components of broadband solar radiation	Relative to the maximum of the phase of solar eclipse, %	Relative to the sums during the period of solar eclipse, %	Relative to the daily totals, %
UV-B 280-315 nm (global)	24.1	13.1	4.0
UV-B 280-315 nm (diffuse)	26.1	12.2	3.6
UV-A 315-400 nm (global)	23.9	13.0	3.4
PAR 400-700 nm (global)	25.7	13.6	3.5
Solar 400-1100 nm (global)	27.2	14.4	3.7
Solar 300-2800 nm (global)	26.9	14.4	3.7
Solar 300-2800 nm (diffuse)	43.5	20.0	4.5
Solar 300-4000 nm (direct)	27.7	16.6	3.7

3. Summary and conclusions

This study was confined to the investigation of the responses of broadband shortwave downwelling solar radiative fluxes in the wavelength range from UV to near IR to the partial annular solar eclipse event of October 3, 2005. Shortwave downwelling solar radiation was measured with the radiometric complex at the ground-based station of the Chisinau site. Measurements were fulfilled with 1-minute averaging interval, which was enough to evaluate the impact of a transient solar eclipse on radiative fluxes. Stability of optical properties of atmosphere over the site was checked with collocated and synchronous measurements of spectral aerosol optical depths with sunphotometer Cimel-318 operating within the frames of global AERONET network. The overall meteorological conditions were good: cloudless sky with light haze during the whole day of observation. Diffuse component of shortwave solar radiation showed the deepest minimum ~43.5% among other components of solar radiation. This was owing to relatively low transparency of the atmosphere with haze. Reduction of daily totals of solar radiation due to solar eclipse varied from 3.4% to 4.5%.

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