RECENT SUNPHOTOMETRY MEASUREMENTS IN ROMANIA, AS PART OF THE AERONET NETWORK

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Rezumat. Lucrarea prezintă măsurările realizate cu fotometrul solar, care este un radiometru automat de scanare a soarelui şi cerului, determinând direct iradianța solară şi radiația cerului la suprafața Pământului. Sunt prezentate analizele statistice a datelor provenite de la stațiile prevăzute cu fotometru solar din România. Toate stațiile sunt conectate la rețeaua AErosol RObotic NETwork (AERONET), fiind analizate doar datele nivelului 1.0.
Cuvinte cheie: aerosol, fotometru solar, AERONET.

Abstract. The paper focuses on results obtained with a sun photometer that is a multi-channel, automatic sun-and-sky scanning radiometer that measures the direct solar irradiance and sky radiance at the Earth's surface. Statistical analyses of data from ground-based sun photometer stations in Romania are presented. All stations are part of the AErosol RObotic NETwork (AERONET), and only data of the level 1.0 have made the objective of this paper.
Keywords: aerosol, sun photometer, AERONET.

1. INTRODUCTION

Aerosols are important constituents of the atmosphere and they play important roles in the global climate change. They affect earth's radiative budget by scattering or absorbing radiation and by altering cloud properties. Atmospheric aerosols are one of the most variable components of the Earth's atmospheric environment, and their influence on energy budget is known. Aerosols play a crucial role in radiative transfer and in the chemical processes that control the Earth's climate [1] [2]. Depending on composition, aerosols can absorb solar radiation in the atmosphere, producing further cooling of the surface and warming the atmosphere. Radiative forcing by aerosols represents one of the most uncertain aspects of climate models since aerosols take on a multitude of shapes and forms and concentrations vary strongly over time and space [3]. Though the main aerosol source is natural, anthropogenic emissions have determinate the aerosol levels' increase in a dramatical way, over the past century. The pollution with particles has been implicated in human health effects, visibility reduction in urban and regional areas, acidic deposition and altering Earth's radiation balance [4].

Aerosol concentrations and size distributions can be derived remotely also through solar direct beam measurements at a range of wavelengths and zenith angles [5] [6] [7] [8]. Sun photometry has the capability of delineating characteristic features of different air masses and the aerosol sources that affect them. Aerosol concentrations and size distributions are driven consequently remotely through solar direct beam measurements, at a range of wavelengths and zenith angles.

The AERONET (AErosol RObotic NETwork) [9] program is a federation of ground-based remote sensing aerosol networks established by NASA and LOA-PHOTONS (CNRS) and is greatly expanded by collaborators from national agencies, institutes, universities, individual scientists, and partners. There are approximately 450 instruments in the world, of which, currently, 4 are located and running in Romania (figure 1), among them one in Timisora, at the POLITEHNICA University, in the multifunctional lab for thermal machines and renewable energies (www.energieregen.mec.upt.ro). The network imposes standardization of instruments, calibration, data acquisition, processing and distribution according a special technique and mathematical model. AERONET collaboration provides globally distributed observations of spectral aerosol optical depth (AOD), inversion products, and precipitable water in diverse aerosol regimes. For Romania, the network is based on the infrastructure and techniques developed in the frame of two main research projects RADO (www.inoe.inoe.ro/RADO) and ROLINET (www.inoe.inoe.ro/ROLINET).

Fig. 1. Map showing positions of the AERONET sun photometer stations in Romania (9).

2. INSTRUMENT DESCRIPTION

The sun photometer is an optical instrument for the measurement of the spectral direct solar radiation direct solar irradiance and sky radiance. The sun photometer is composed of an optical head, an electronic box and a robot (fig. 2 and 3). The optical head has two channel systems: the sun collimator, without lens, and the sky collimator with lenses. The sun tracking is equipped with a 4-quadrant detector. The electronic box contains two microprocessors for real time operation, for data acquisition and motion control. In automatic mode, a 'wet sensor' detects precipitation and forces the instrument to park and to protect the optics. The robot is moved by step-by-step motors in two directions: in the zenith and azimuth planes.

Fig. 2. Sun photometer located at the Politehnica Univerity of Timisoara (45.74 N, 21.22E).

All the sun photometer from Romania are manufactured in Paris, France by company Cimel Electronique. In table 1 is a list of all the stations from Romania connected to federal network AERONET.

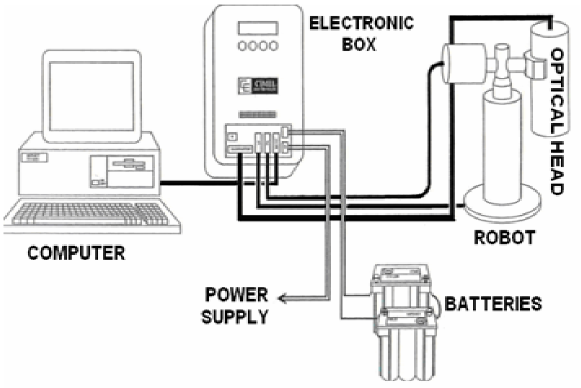

Fig. 3. Components of a sun photometer.

Table 1

List of AERONET sun photometer stations from Romania

AERONET Stations	Coordinates of the Measuring Point	Data recorded from
Bucharest	44.38 N, 26.02 E	03.07.2007
Eforie	44.07 N, 28.63 E	11.09.2009
Cluj Napoca	46.76 N, 23.55 E	05.07.2010
Timisoara	45.74 N, 21.22 E	06.02.2011

3. MEASUREMENT CONCEPT

The direct Sun measurements are achieved in eight spectral bands requiring approximately 10 seconds. Eight interference filters at wavelengths of 340, 380, 440, 500, 670, 870, 940 and 1020 nm are located in a filter wheel, which is rotated by a direct drive stepping motor. The 940-nm channel is used for column water abundance determination. A pre-programmed sequence of measurements is taken by these instruments starting at an air mass of 7 in the morning and ending at an air mass of 7 in the evening. The optical thickness is calculated from the spectral extinction of direct beam radiation at each wavelength based on the Beer–Bouguer law. Attenuation, due to Rayleigh scattering, absorption by ozone and gaseous pollutants, is estimated and thus enabling isolat the aerosol optical thickness. A sequence of three such measurements, taken every 30 seconds apart, creates a triplet observation per wavelength. During the large air mass periods, direct Sun measurements are made at regularly 0.25 air mass intervals, while at smaller air masses the interval between measurements is typically 15 minutes. The time variation of clouds is usually greater than that of aerosols causing an observable variation in the triplets that can be used to screen clouds in many cases. Additionally, the 15-minute interval measurements allow, for a longer temporal frequency, to check for cloud contamination.

Sun photometer measures the spectral extinction of the direct solar radiation. This is expressed in the Beer-Lambert-Bouguer law:

$$V(\lambda) = V_0(\lambda)\left(\frac{d_0}{d}\right)^2 e^{(-m\cdot\tau_t(\lambda))} \qquad (1)$$

where: V is the voltage, in V; λ – the wavelength, expressed in m; V_0 – the extraterrestrial voltage; d – the earth - sun distance, in m; d_0 – the average earth - sun distance, in m; m – the air mass; τ_t – the total atmospheric optical depth.

Direct solar radiation is measured through filter bands with center wavelengths of λ and in terms of V, voltage. This signal is a function of the instrument's extraterrestrial voltage, V_0, which expresses instrument calibration, d_0 the average earth–sun distance, d the earth–sun distance on the day of observation, m is the air mass, and τ_t the total atmospheric optical depth.

Figure 3 shows the average AOT at 440 nm for the 4 AERONET stations from Romania, as presented in Table 1.

Figure 4 illustrates the mean relative weekly variability of AOT at 500 nm for all the 4 mentioned AERONET stations situated in Romania.

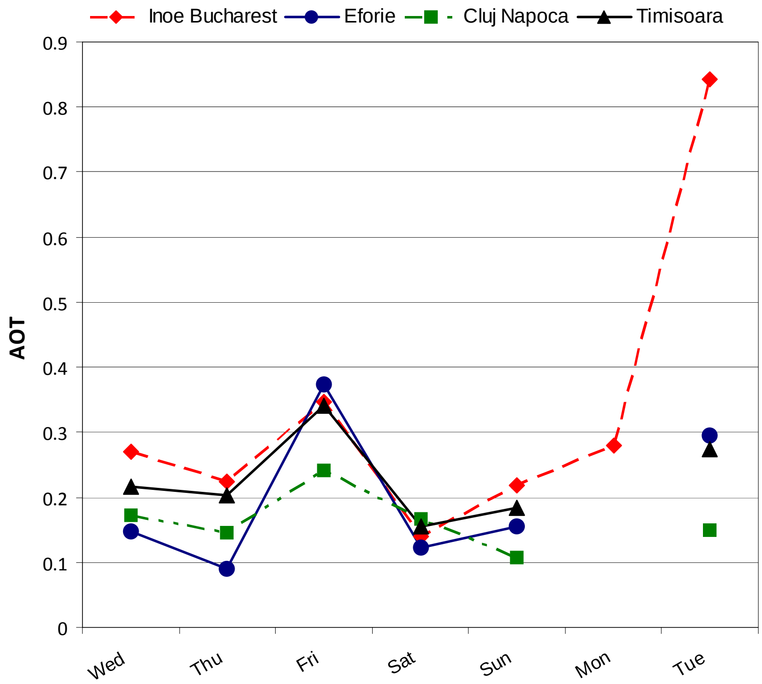

Fig. 3. Average AOT measured at a wavelength 440 nm for week 9-15 February 2011.

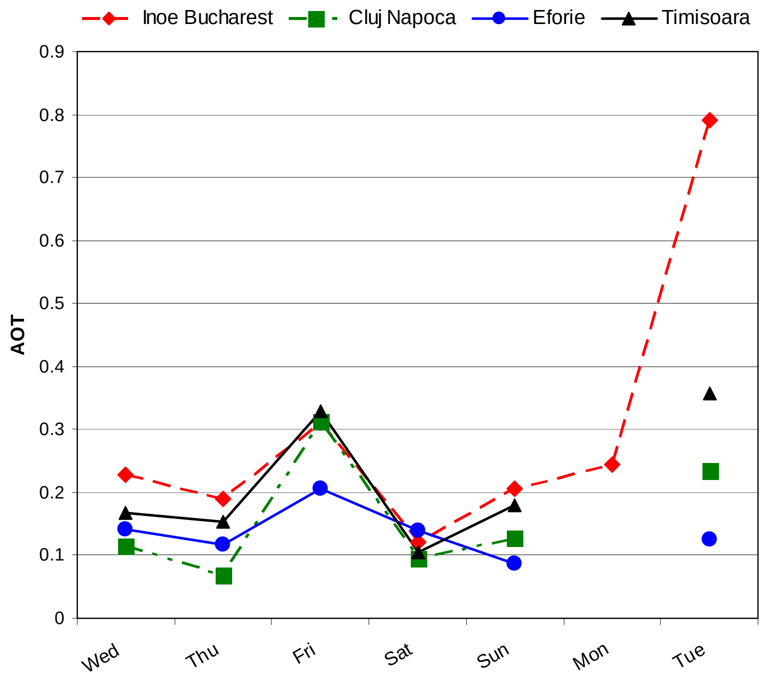

Fig. 4. Average AOT measured at a wavelength 500 nm for week 9-15 February 2011.

On February 14 data was recorded only in one location (Bucharest) because in other stations the sky was overcast.

An optical thickness of less 0.1 indicates a crystal clear sky with maximum visibility, whereas a value of 1 indicates very hazy condition.

Main possible aerosol sources for Bucharest, Timisoara and Cluj are urban pollution, dust intrusions and for Eforie are maritime aerosol, urban pollution from nearby Constanța city and dust intrusions.

4. CONCLUSIONS

The sun photometer is an optical instrument appropriate to accomplish investigations and conclusions based on real time measurement of the spectral direct solar radiation and transmission of automatic measurements via the geostationary satellites METEOSATS. The spectral resolution depends on the number of channels. The range of wavelength is most between 0.35-1.05 μm. The total optical thickness (AOT) or aerosol optical depth (AOD) of the atmosphere can be determined based on the measured direct solar radiation. Aerosol optical depth is important information for identifying the climate effects of aerosols.

Sun photometry proves to be a very useful tool to distinguish between different types of aerosol loading in the atmosphere.

Acknowledgments

This work was partially supported by the strategic grant POSDRU/88/1.5/S/50783, Project ID50783 (2009), co-financed by the European Social Fund-Investing in People, within the Sectoral Operational Program Human Resources Development 2007-2013.

We thank: Prof. Sabina Ştefan, Dr. Phys. Doina Nicolae, Nicolae Ajtai, and their staff for establishing and maintaining the three sites used in this investigation.

Also the authors wish to acknowledge Norway Grants for RADO contract STVES 115266 (http://inoe.inoe.ro/RADO)

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