PRESENT ENVIRONMENT AND SUSTAINABLE DEVELOPMENT, NR. 4, 2010

RADIOMETRIC MEASUREMENTS IN EASTERN MOLDAVIA. CORRELATIONS BETWEEN TOTAL CLOUDINESS AND THE SUNSHINE DURATION

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Key words: ultraviolet solar radiation, erithermal solar radiation, UV index.

Abstract. Because during a period of time with clear sky, a maximum of solar radiation is obtained, it is obvious that the degree of sky coverage and the cloud type influence the sunshine duration and thus solar radiation (global solar radiation). In the case of both direct and diffuse solar radiations, cloudiness represents one of the key factors which influence their variation. Our purpose is to obtain information on some meteorological parameters (global, diffuse, direct solar radiations etc.) and to underline their close connection to the sunshine duration, as well as the degree of sky coverage, registered at the weather stations in the eastern part of Moldavia.

Introduction

A great amount of energy is emitted by the Sun into the cosmic space (5.316×10^{27} cal ≈ 2.225×10^{25} kJ in one minute). Out of this total amount, the Earth gets only a very small part (approximately a second billion part).

Of the total amount of solar radiation at the upper limit of the atmosphere, 7% goes to the ultraviolet radiations, 47% goes to the visible radiations of the spectrum and 46% to the infrared radiations.

In the solar spectrum, the maximum energy corresponds to the radiation with the wavelength of 0.475 μm, value which allowed for the calculus of the temperature at the Sun surface.

Because the greatest part of solar radiation lays in the short-wavelength region, it was conventionally established that the solar radiation which comes from the Sun (direct and diffuse) should be named *short wave radiation*, unlike the radiations emitted by the atmosphere and the surface of the Earth, which are called *long wave radiations* (Neacşa, Berbecel, 1979).

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1. Theoretical notions and physical parameters

Before it gets to the surface of the Earth, solar radiation travels a long way through the terrestrial atmosphere and during this time it undergoes major changes. Thus, a part of the radiant energy is absorbed by the atmosphere and is transformed in other forms of energy (especially caloric); another part is diffused into the atmosphere by the gas molecules and the very small particles, both solid and liquid, which form air suspensions. Finally, partially, the solar radiation received at the upper limit of the terrestrial atmosphere is reflected back into the cosmic space (especially by the clouds).

The absorption of the solar energy has a selective character (it occurs in the case of certain wavelengths).

In the category of atmospheric components which display a more important absorption of the solar radiations, we mention the ozone, which acts especially on the ultraviolet radiations, water vapors and carbon dioxide, which absorb the infrared radiations.

The absorption produced by the other atmospheric gases is less important. We do mention an important behavior feature of the atmosphere: it is transparent enough for the visible radiations of the solar spectrum and less transparent for ultraviolet and particularly for infrared radiations (Neacşa, Berbecel, 1979).

The energy emitted by different objects is called *radiation*. The radiant energy is one of the most important forms of energy (Mutu, 2008).

Radiometry studies the radiative exchanges (solar radiation, atmospheric and terrestrial) that occur in the atmosphere –terrestrial-surface system.

In meteorology, we only deal with thermal or caloric energy. The energy of radiation is measured in thermal units, named *calories*.

Solar radiation is made up of: direct radiation, diffuse, global and reflected radiation.

Direct radiation contains the solar radiant energy that reaches the surface of the Earth. It depends on several factors: the height of the Sun, nebulosity (cloudiness) and the transparence of the atmosphere, but also the latitude of the observation point.

Diffuse radiation is the radiation resulted mainly from the phenomenon of molecular diffusion, determined by the presence of some solid and liquid particles in the atmosphere. *The flux of diffuse radiation* represents, usually, the energy of the diffused radiation received by one square centimeter of horizontal surface in one minute. It depends both on the height of the Sun and the transparence of the atmosphere (it grows together with these) and on the cloudiness (all the clouds in the sky) – the upper clouds decrease the intensity of direct radiation, therefore the flux of diffuse radiation increases; the lower clouds absorb the direct radiation, thus the flux of diffuse radiation decreases; in the case of medium clouds, the flux of diffuse radiation increases significantly.

Global radiation refers to the sum of all the radiation fluxes (direct and diffuse) on a horizontal surface. It grows together with the reduction of latitude.

Reflected radiation is the part of the incident radiation at the surface of the Earth which is reflected by the atmosphere. The *reflection factor* of a surface is called *albedo* (Oprea, 2005).

In order to determine the intensity of direct radiation in absolute units, pyrheliometers are used. Actinometers measure the intensity of direct radiation in relative units. Therefore, if we use the actinometer in order to measure the intensity of direct radiation, we should first calibrate it as compared to the absolute instrument – the pyrheliometer. All these instruments are called *radiometers*.

In most cases, the cloud determines the aspect of weather in the area above which it exists. It represents one of the most important phenomena dealt with by meteorological observation.

Total cloudiness represents the degree of sky coverage with all types of clouds; the low cloudiness refers only to the clouds whose basis is situated at the inferior level. The observations concerning nebulosity are generally made from the meteorological platform. Total and low cloudiness are usually expressed in tenths (eighths) of the sky. In order to establish the total cloudiness, the sky is imaginarily divided into ten (eight) equal parts (tenths/eighths) and then they establish how many of these are covered by clouds.

The sunshine duration represents the period of time, during one day, in which the Sun has shone in the sky.

At the weather stations, the observations concerning the sunshine duration are made by using the heliograph.

The functioning of the heliograph is based on the propriety of a glass ball (crystal) of concentrating in its focus the rays of Sun which fall on its surface and of producing a burn on a diagram (heliogram) placed behind the sphere.

The apparent movement of the Sun on the sky, from East to West, makes the burn on the heliogram take the shape of a trail. According to the length of this trail (or that of the sectors behind) the sunshine duration can be determined. Replacement of heliograms is done daily, after sunset, with or without it having anything registered. Sunshine duration is expressed in hours and tenths of hours.

2. Data and working methods

In order to make this study, we used the radiation data provided by the weather stations in Galati (69 m altitude) and Iasi (102 m altitude). Both stations are situated in the eastern half of Moldavia and only at these stations, radiometric measurements have been made since 1970 and 1963, respectively. For our study, we have utilized average values of the solar direct radiation on a normal surface ($cal \cdot cm^{-2} \cdot min^{-1}$) and according to the WMO (World Meteorological Organization), we transformed $cal \cdot cm^{-2} \cdot min^{-1}$ in $W \cdot m^{-2}$; we have also used total cloudiness expressed in tenths and the sunshine duration, in hours and tenths of hour.

For the same purpose, we have used data from the ECMWF server (European Centre for Medium-Range Weather Forecasts)–Era Interim Data, Era 40 respectively. In order to manipulate the data, we have used GrADS (Grid Analysis and Display System). In order to compare the obtained data, we have used the conclusions and data in paper (Oprea, 2005).

3. Data interpretation

As far as the sunshine duration is concerned, we have used the data for the period 2001-2008 and we concluded that the sunshine duration registered at the weather station in Iasi was of 2067.6 hours/year, thus being in accordance with the limit of 2000-2100 hours/year (1961-2000) (fig. 1).

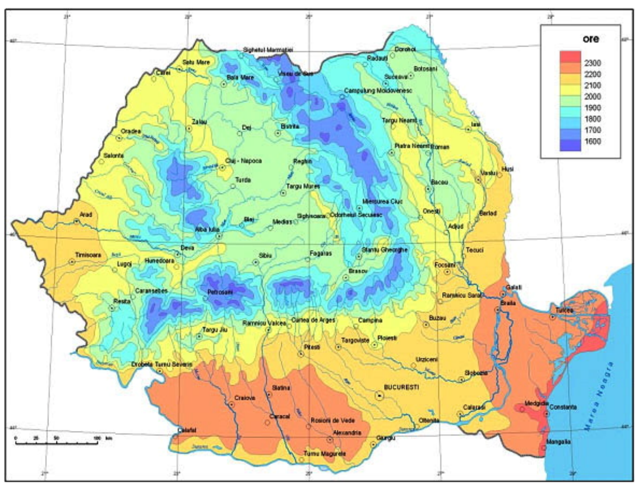

Fig. 1 - The total annual average sunshine (1961-2000) - Clima României, 2009

For the Galati area, the sunshine duration registered at the weather station in Galati is of 2259.26 hours/year, value which is in accordance with the limit of 2200-2300 hours/year (1961-2000) (fig.1). We may, therefore, state that the sunshine duration during one year did not suffer any changes.

By analyzing the total cloudiness (expressed in fractions of clouds) in the last 18 years, the data obtained by ERA40 re-analysis (ECMWF) show that the average total cloudiness in the Iasi area is greater than that in the Galati area (6.53>6.03). This fact can be noticed in figs. 2 and 3.

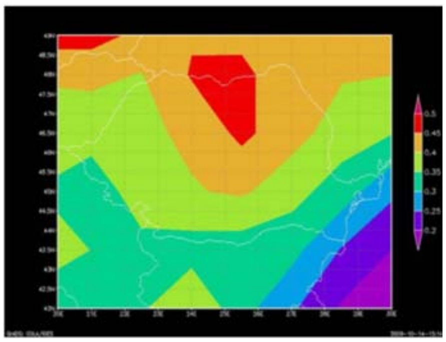

Fig. 2 - Total cloudiness in the warm season (the month of June, 1990-2008)

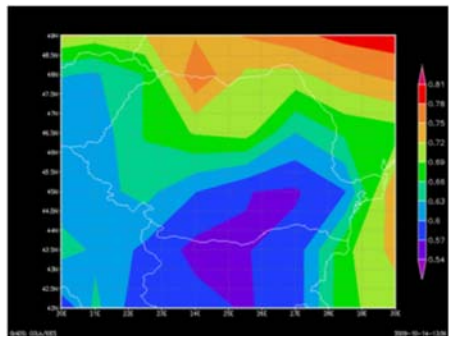

Fig. 3 - Total cloudiness in the cold season (the month of December, 1990-2008)

Figure 2 shows that for the warm season, in the Iasi area, the total cloudiness (cloud fraction between 0.40 and 0.45) is greater than in the Galati area (cloud fraction between 0.35 and 0.40).

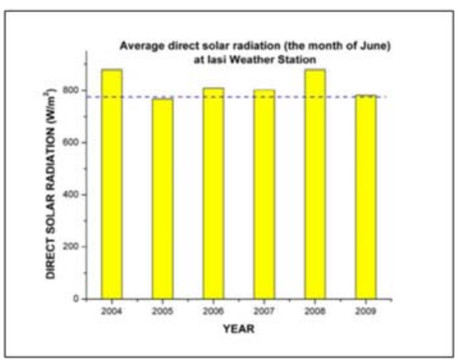

Fig.4 - Average direct solar radiation (the month of June) at Iasi Weather Station

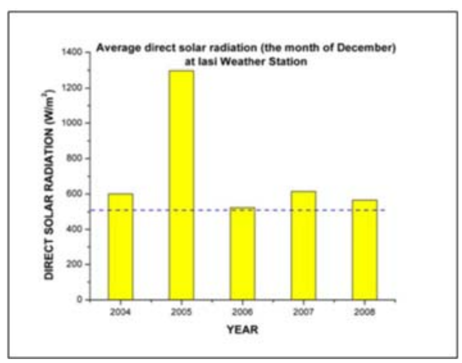

Fig. 5 - Average direct solar radiation (the month of December) at Iasi Weather Station

Figure 3 shows that, for the cold season in the Iasi area, the total cloudiness (cloud fraction between 0.66 and 0.69) is greater than that of the Galati area (cloud fraction between 0.60 and 0.63).

For the data concerning the direct solar radiation, for technical reasons, we managed to obtain data from the weather station at Iasi, only for the period of

2004-2009, while from the weather station at Galati, only for the period of 2007-2009.

According to the calculations reported in Ref. [3], for the month of June (hour 12 UTC), the average direct solar radiation for the Iasi area is of 775 W/m^2, while for the Galati area its value is of 718 W/m^2. For the month of December (hour 12 UTC), the average direct solar radiation for the Iasi area is of 509 W/m^2 and for the Galati area this value is of 496 W/m^2.

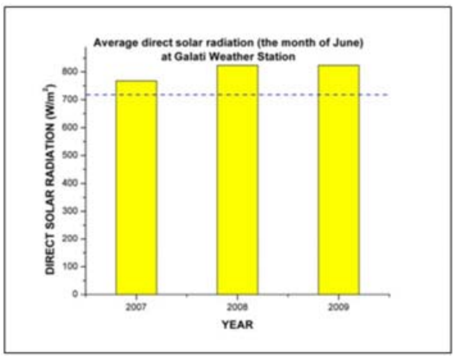

Fig.6 - Average direct solar radiation (the month of June) at Galati Weather Station

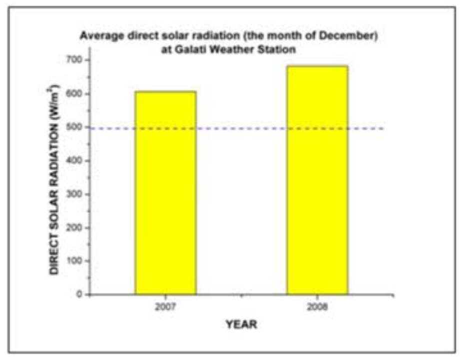

Fig. 7 - Average direct solar radiation(the month of December) at Galati Weather Station

Iasi area. For the month of June, in the Iasi area, between 2004 and 2009, we obtained average values greater than the value of 775 W/m^2, except for the year of 2005. For the month of December, in the Iasi area, between 2004 and 2009, we obtained average values exceeding the value of 509 W/m^2. This can be noticed in Figs. 4 and 5.

Galati area. For the month of June, in the Galati area, between the years 2007 and 2009, we obtained average values greater than the value of 718 W/m^2. For the month of December, in Galati area, for the period 2007-2008, we obtained average values over 496 W/m^2. This can be noticed in Figs. 6 and 7.

Conclusions

For the Iasi weather station, the sunshine duration was of 2067.60 hours/year, in accordance with the limit of 2000-2100 hours/year (1961-2000). As for the Galati weather station, the sunshine duration is of 2259.26 hours/year, which is in accordance with the limit of 2200-2300 hours/year (1961-2000).

In the warm season (representative month–June), the average of total cloudiness for the last 18 years decreases almost half the average obtained during the cold season (representative month–December). The characteristic of both seasons is the fact that the total nebulosity is greater in the northern area and it decreases as we move towards the southern area.

From the analysis of total cloudiness between the years 1990 and 2008, we concluded that the average value of the total cloudiness at the Iasi weather station is greater than respective value registered at the weather station in Galati. (6.53>6.03)

If during the cold season, a decrease of the average total cloudiness from the northern part towards the southern part of the region could be noticed, for the warm season, this decrease is more diminished due to the poor presence of lower cloudiness.

The decrease of 2005 in direct solar radiation for the Iasi area could be caused by the fact that the moth of June of that year was a rainy one, with high cloudiness, while the increase for the month of December of the same year could be caused by insignificant nebulosity.

Even though the meteorological elements have maintained their "constancy" with the passing of time, an increase of direct solar radiation beginning with the year of 2004 has been noticed, during both the warm and cold season, although we began our study with the same initial data.

Acknowledgements. Authors gratefully acknowledge Mr. Ovidiu Machidon for kindly providing radiometric data.

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