ASSESSMENT OF THE QUALITY OF INCOMING SOLAR RADIATION DATA FROM CONVENTIONAL AND AUTOMATED WEATHER STATIONS[1]

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ABSTRACT - The quality of measured incident solar radiation data from three locations was evaluated. Twenty-two years of data (1978-2001) from Piracicaba, Brazil (22°42'30" S, 47°38'00" W, 546 m a.s.l.), 15 years of data (1989-2002) from Maricopa, Arizona (33°04'07" N, 111°57'08" W, 361 m a.s.l.), and 14 years of data (1998-2001) from Pelotas, Brazil (31°52'00" S, 52°21´24" W, 13 m a.s.l.) were used. The data for all places were obtained by downloading from the respective web site. Measured solar radiation was compared on a daily basis to estimated clear sky solar radiation, which represents the maximum theoretically solar radiation striking on a horizontal surface in a given day. Correction coefficients were determined indicating the existence of systematic errors in the measurements probably due to sensor improper calibration or instrument malfunctioning. Among the sites, Piracicaba was the one for which radiation data had to be correct with higher frequency.

INTRODUCTION

Solar radiation at the top of atmosphere is attenuated during its path before reaching the surface. The magnitude of attenuation will basically depend upon cloudiness, aerosols and gases content, which affect the absorption, reflection and scattering of the radiation. The solar radiation recorded over a given period of time on a horizontal plane is due to a direct beam (R_d) and a scattered beam of radiation (R_{sc}). The total radiation recorded by the instrument at that level is then called global solar radiation (R_s).

Information on R_s has important applications on many fields of studies, including agro ecological zoning, evapotranspiration and water management (Allen et al., 1998), use of solar energy (Duffie & Beckman, 1974), and animal and crop production under cover (Takakura, 1993; Reis & Makishima, 2002). Solar radiation data are also required in crop growth models to simulate physical and physiological processes such as photosynthesis, biomass production and evaporation (Hook & McClendon, 1992).

Pyranometers are the instruments used to measure R_s in both conventional and automated weather stations. Care must be taken when using such instruments so that the measurement is precise and reliable as much as possible. Problems of inadequate installation and operation and malfunctioning and improper calibration are associated to low quality data. Then, besides checking periodically the instruments for good operation, the data should be screened for quality problems. In evapotranspiration (ET) studies, for example, Allen (1996) pointed out that estimates of reference ET are no better than the weather data upon which they are based.

In order to evaluate the quality of R_s data, ALLEN (1996) suggested that pyranometer operation and calibration accuracy could be evaluated by plotting daily average pyranometer readings against computed short wave radiation expected under clear sky conditions. The proposed methodology was used to investigate the quality of R_s data from conventional and automated weather stations from three locations in Brazil and the United States. Correction coefficients were proposed to adjust the data using clear sky solar radiation as reference.

MATERIAL AND METHODS

Table 1 gives some detailed information on the locations from which solar radiation data were used.

Table 1. Local geographical coordinates type of weather station, measuring period and corresponding solar radiation sensor used. (I = Piracicaba, Brazil; II = Maricopa, Arizona, III = Pelotas, Brazil, CWS = conventional weather station, and AWS = automated weather station).

Site	Geographical coordinates			Weather station type and data period		Sensor
	Lat. (grau)	Long. (grau)	Alt. (m)	CWS	AWS	
I	-22.71°	-47.63°	546	1978 to 2001	1998 to 2001	S1 and S2
II	33.07°	-111.95°	361	-	1989 to 2002	S2
II	-31.87°	-52.36°	13	-	1998 to 2001	S2

S1 = Robitsch bimetal pyranometer (used in conventional weather stations) and S2 = silicon cell pyranometer (used in automated weather stations)

The daily incoming solar radiation expected under clear sky conditions (R_{so}) on a horizontal plane is the maximum theoretical value for R_s that can occur on a given day. Therefore one can assume that R_s values above the R_{so} curve indicate the likelihood of errors in calibration of the sensor (Allen, 1996). Similarly, a consistent and uniform drift of measured R_s values below the R_{so} curve is an indication of the likelihood of improper calibration or instrument malfunctioning. Then, R_{so} was adopted as a reference to evaluate the quality of measured R_s and obtained as follows:

$$R_{so} = \left(0.75 + 2\cdot 10^{-5}\cdot A\right)\cdot R_o \qquad (1)$$

where R_{so} and R_o have units of MJ m^{-2} day^{-1} and A is local altitude (m). R_o is the extraterrestrial solar radiation and it was calculated according to Allen et al. (1998). The ratio R_{so}/R_o is the atmosphere clearness

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index, which depends on the atmospheric clarity and elevation and sun angle.

Based on the assumption that R_{so} is the maximum theoretical solar irradiance on a given day, daily measured values of R_s and daily computed values of R_{so} were plotted against time for all years of the data period as given in Table 1. The procedure was applied for conventional and automated weather station data.

Where measured R_s data consistently lied above or below the predicted R_{so} envelope a correction factor was developed so that the R_s could adjust to the R_{so} curve.

RESULTS AND DISCUSSION

Problems with measured R_s data from a conventional weather station were found in all years for Piracicaba (Table 2), except for the year 1985. In some of the years R_s was underestimated and overestimated in others as compared to the respective R_{so} envelope. Two correction factors have to be used in 1981 and 1984 (Table 2) due to occurrence of both under and overestimation of R_s data over the years.

In Maricopa, corrections in R_s data were only required in 1992 and 1993 since measured R_s was systematically below estimated R_{so} over both years.

Table 2. Factors for correcting R_s data according to the period, location, and weather station type.

Year	Site and weather station type			
	I CWS	I AWS	II AWS	III AWS
1978	1,07	-	-	-
1979	1,30	-	-	-
1980	1,37	-	-	-
1981	1,35 – 0,87	-	-	-
1982	0,83	-	-	-
1983	0,87	-	-	-
1984	0,88 – 1,00	-	-	-
1985	1,00	-	-	-
1986	1,05	-	-	-
1987	1,16	-	-	-
1988	1,18	-	1,00	-
1989	1,18	-	1,00	-
1990	1,18	-	1,00	-
1991	1,18	-	1,00	-
1992	1,18	-	1,08	-
1993	1,18	-	1,05	-
1994	1,18	-	1,00	-
1995	1,20	-	1,00	-
1996	1,18	-	1,00	-
1997	1,07	-	1,00	-
1998	1,05	1,05	1,00	1,00
1999	1,05	1,05	1,00	1,00
2000	1,05	1,05	1,00	1,00
2001	1,05	1,05	1,00	1,00

No need of correction was found for the Pelotas data in all years, according to Table 2. For this site, Figure 1 shows an example of distribution of daily measured R_s data and R_{so} and R_o data over the year 1998. Figure 2 refers to the year 1981 for Piracicaba, Brazil, as an example of situation where correction factors had to be applied in order to correct the R_s with respect to R_{so} values.

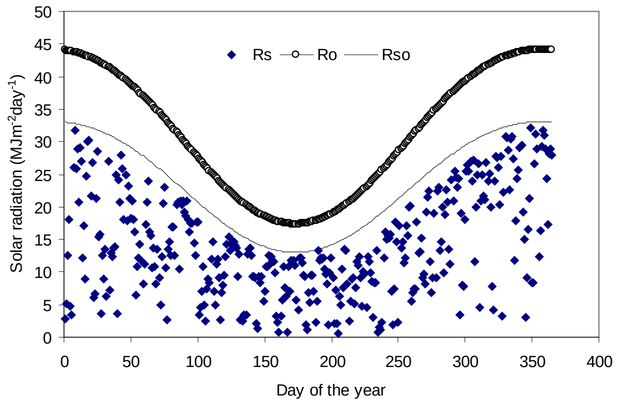

Figure 1. Plot of measured solar radiation (R_s), clear sky solar radiation (R_{so}), and extraterrestrial radiation (R_o) for year 1998 for Pelotas, Brazil

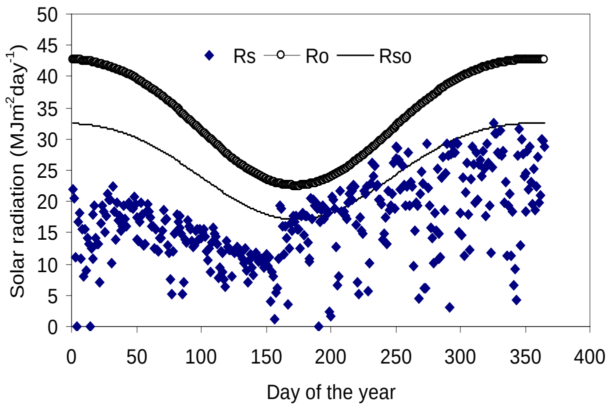

Figure 2. Plot of measured solar radiation (R_s), clear sky solar radiation (R_{so}) and extraterrestrial radiation (R_o) for the year 1981 for Piracicaba, Brazil. The correction factor 1.35 was used in the first half and the 0.87 used in the second half of year.

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