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Trends in solar radiation in NCEP/NCAR database and measurements in northeastern Brazil

Vicente de Paulo Rodrigues da Silva [a,*], Roberta Araújo e Silva [a], Enilson Palmeira Cavalcanti [a], Célia Campos Braga [a], Pedro Vieira de Azevedo [a], Vijay P. Singh [b], Emerson Ricardo Rodrigues Pereira [a]

[a] *Federal University of Campina Grande/Center of Technology and Natural Resources/Academic Unity of Atmospheric Sciences, Av. Aprígio Veloso, 882, Bodocongó, 58109 970, Campina Grande, PB, Brazil*
[b] *Dept. of Biological and Agricultural Engineering, Texas A&M Univ., TX 77843-2117, USA*

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Abstract

The database from the National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) re-analysis project available for the period from 1948 to 2009 was used for obtaining long-term solar radiation for northeastern Brazil. Measurements of global solar radiation (R_s) from data collection platform (DCP) for four climatic zones of northeastern Brazil were compared to the re-analysis data. Applying cluster analysis to R_s from database, homogeneous sub-regions in northeastern Brazil were determined. Long times series of R_s and sunshine duration measurements data for two sites, Petrolina (09°09′S, 40°22′W) and Juazeiro (09°24′S, 40°26′W), exceeding 30 years, were analyzed. In order to exclude the decadal variations which are linked to the Pacific Decadal Oscillation, high-frequency cycles in the solar radiation and sunshine duration time series were eliminated by using a 14-year moving average, and the Mann–Kendall test was employed to assess the long-term variability of re-analysis and measured solar radiation. This study provides an overview of the decrease in solar radiation in a large area, which can be attributed to the global dimming effect. The global solar radiation obtained from the NCEP/NCAR re-analysis data overestimate that obtained from DCP measurements by 1.6% to 18.6%. Results show that there is a notable symmetry between R_s from the re-analysis data and sunshine duration measurements.

Keywords: Global dimming; Mann–Kendall test; Net radiation; Pacific Decadal Oscillation

1. Introduction

Solar radiation drives almost all physical, chemical and biological processes in the earth's atmospheric system. Long-term trends in solar radiation have received an increasing attention due to its large influence on the hydrological cycle. Using a deterministic radiation transfer model and data from NCEP/NCAR re-analysis, Hatzidimitriou et al. (2004) determined a decadal increase in the outgoing longwave radiation at the top of the atmosphere. Others studies have also shown a mix (increasing and decreasing) of statistically significant trends in outgoing longwave radiation at the top of the atmosphere (Chen et al., 2002) and surface reflected solar radiation (Tashima and Hartmann, 1998). The average amount of sunlight reaching the ground has been decreasing in some parts of the world (Liepert and Kukla, 1997; Liepert, 2002). Otherwise, several studies have suggested that the increasing trend of approximately 0.5–0.7 °C in global temperature over the last century may have solar origin (Abakumova et al., 1996; Fotiadi et al., 2005). The "global dimming"

* Corresponding author. Tel./fax: +55 8333101202.
E-mail address: vicente@dca.ufcg.edu.br (V.P.R. Silva).

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effect refers to observed reduction in solar radiation reaching the earth's surface in the last 50 years in some places of the world, and it suggests several consequences as regards climate, particularly the hydrological cycle (Nazarenko and Menon, 2005). The NCEP/NCAR re-analysis project provides daily data (1948-present) of several atmospheric variables, including solar radiation (Kalnay et al., 1996). These data can be used for assessing climate variability which is perhaps the greatest threat to life on Earth.

A major source of inter-annual climate variations in several parts of the globe is the El Niño/Southern Oscillation (ENSO) (Kayano and Andreoli, 2007). For example, the ENSO cycle explains a large part of the inter-annual rainfall variability in South America (Grimm, 2003; Vera et al., 2004). On the other hand, Kayano and Andreoli (2004) reported that the decadal variations (9–14 year) of the northern NEB (northeastern Brazil) rainfall are linked to the Pacific Decadal Oscillation (PDO) or to the sea surface temperature (SST) decadal variations in the tropical South Atlantic (TSA). Obviously, decadal cycles observed in rainfall over northeastern Brazil are closely associated with variation in cloudiness which therefore impacts solar radiation. Decadal-scale fluctuations are crucial particularly to northeastern Brazil, because they control water supplies and may modulate higher frequency events such as floods and droughts. The presence of various motion scales in time series may complicate the analysis and interpretation of long-term trends of meteorological variables. Thus, the cycles must be accurately removed before performing statistical tests, which require that the data be statistically independent and identically distributed for detecting long-term trends (Eskridge et al., 1997).

Since the solar renewable energy community has long depended upon solar radiation measurements (Gueymard and Myers, 2009), the knowledge of solar resource at the earth surface, with enough accuracy, is essential for planning any solar energy system at a given location (Zarzalejo et al., 2009). However, the necessary equipments for solar energy measurements are available only at a few places. As a consequence, many models for estimation of solar radiation have been developed as a function of other climatic variables, such as sunshine duration (El-Metwally, 2004; Chineke, 2008; Bakirci, 2009). On the other hand, solar radiation derived from satellite images or re-analysis data can be advantageous for characterization of solar resource over large areas. In addition, a stochastic model based on cloudiness observations for simulating global solar radiation on a horizontal surface has also been developed (Ehnberg and Bollen, 2005).

One of the main limitations of the methods, based on meteorological data, that are commonly available is that they require calibration using on-site measurements of solar radiation data and it is therefore open to question how transferable these calibration values are to other locations. Obviously, measured data is the best form of this knowledge; however, there are very few meteorological stations with measurement of global solar radiation, particularly in developing countries (El-Metwally, 2005). A large number of studies on changes in solar radiation and sunshine duration have been also published (Power and Goyal, 2003; Liu et al., 2004; Power and Mills, 2005). Despite all of these studies, there is very scarce information on global dimming effect in Brazil. This effect has received limited attention and it is thus poorly understood. The objective of this study is to assess trends in solar radiation in northeastern Brazil using the NCEP/NCAR database and surface measured data; analyze trends in measured global solar radiation and sunshine duration obtained from data collection platform (DCP) by a non-parametric test; analyze the global dimming effect in the region of study; and measure the accuracy of re-analysis data as compared to DCP data using statistical indicators.

2. Data and methods

2.1. Study area

The region chosen for this study is the northeastern Brazil which covers an area of about 1.5 million square kilometers and borders the Atlantic Ocean on the north and east side. The semiarid part of the region is inhabited by more than 30 million people and presents a large variability in both inter-annual and spatial rainfall (Silva, 2004). This area is extremely vulnerable to the combined effects of natural hazards and human activity. Fig. 1 shows the map of northeastern Brazil, including the spatial distribution of the NCEP/

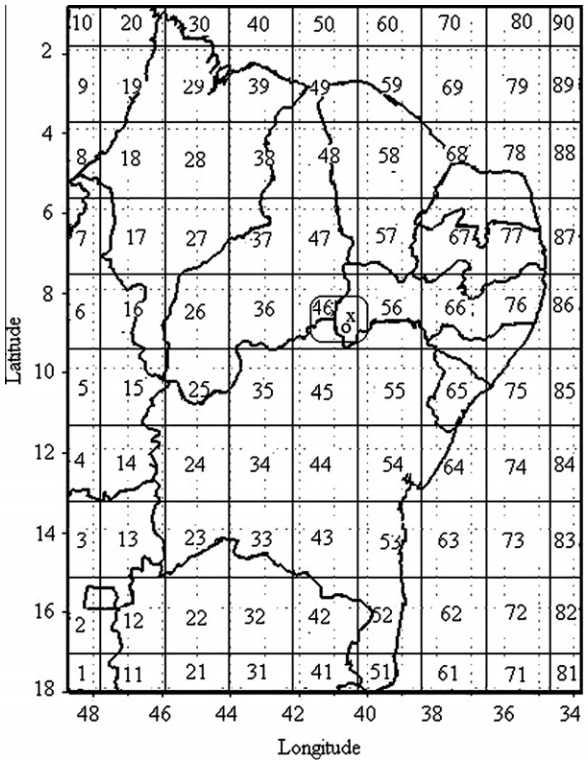

Fig. 1. Spatial distribution of the NCEP/NCAR grid points in a tropical region (1°S–18°S; 33°W–48 W°) with 90-grid points over northeastern Brazil. Each grid point has 2.5° longitude–latitude resolution.