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Review

Extreme global solar irradiance due to cloud enhancement in northeastern Brazil

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ABSTRACT

Extraterrestrial radiation is attenuated by the atmosphere in different proportions depending mainly on the solar zenith angle and the altitude of the measurement point. In this work, very high and extreme total solar irradiance measurements are presented that, on some days, surpassed the Solar Constant corrected by the actual Sun-Earth distance (CSC).

This paper reports a detailed analysis of ground-based measurements of cloud-enhanced solar global irradiation in NE Brazil in the cities of Água Branca, Santana do Ipanema, Palmeira dos Índios, Laje, Pão de Açúcar, Arapiraca, Coruripe, and Maceió from January to December 2008. Measurements were made at 1-min intervals using Eppley and B & W pyranometers with an estimated uncertainty of 5%.

It was found that a) the phenomenon is not uncommon and that it occurs on at least one-third of the days in a given month; b) the cumulative duration (number of 1-min consecutive events) can reach 34 min; d) there is a clear seasonal effect, and the probability of occurrence on a monthly basis shows two peaks, one in April and another in October; e) the most extreme solar radiation was 1650 W/m^2 in Água Branca, which is approximately 350 W/m^2 above the extraterrestrial solar irradiation; and f) a strong asymmetry was detected in the occurrence profile between the morning and afternoon.

Finally, the observation of extreme values should be taken into account in the study of solar radiation effects related to the UV index and biological effects, among others. Extreme radiation above the extraterrestrial irradiance lasting up to 30 min can mean very high and potentially dangerous UV (UVI) indexes, even in situations with seemingly adequate cloudiness.

Contents

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Nomenclature

B	Direct component
B&W	Black and White pyranometer from Eppley.
CSC	Solar Constant corrected by the actual Sun-Earth distance
D	Diffuse component
DEN	Department of Nuclear Energy
ESRA	European Solar Radiation Atlas
ε	The correction factor for the variation of the sun-earth distance
FAE	Research Group on Alternative Sources of Energy
G	Horizontal global solar irradiation
I_0	Solar constant
m	Relative air mass
min	Minute
R_o	Average Sun-Earth distance
SORCE	Satellite's data
T_{L2}	Linke turbidity factor for air mass 2
UFPE	Federal University of Pernambuco
UT	Local Time
UV	Ultraviolet
UVI	Ultraviolet index
W	Watt
WRC	World Radiation Center
$\delta_R(m)$	Integral Rayleigh thickness
γ_s	Solar altitude angle
Δ	Statistical distribution of the difference between the measured values of extreme solar irradiation and the extraterrestrial irradiation

1. Introduction

The total solar irradiance is a very important variable that significantly influences the Earth's environment. It is the main source of energy for life on Earth, and its interaction with the atmosphere determines the physical conditions of the air (temperature, pressure, humidity, clouds). Solar radiation has an inhomogeneous distribution among different geographical regions of the Earth and times of day due to a large number of factors: the apparent movement of the Sun in the sky, the Sun-Earth distance, geographical coordinates (latitude, longitude and altitude), and the atmospheric state, including clouds and ground reflectivity, among others. The positive correlation of different factors can yield irradiance values on the order of or even larger than the extraterrestrial radiation during short periods of time around noon [1–3]. The Solar Constant is the value of the extraterrestrial solar irradiance incident on a surface at perpendicular incidence and at the average Sun-Earth distance (R_o). During the period studied, the Solar Constant varied less than 0.015%, from 1365.4 W/m^2 to 1365.2 W/m^2, as given by the World Radiation Center (WRC) at Davos, Switzerland [4]. For our analysis, we will employ these values, but it must be noted that the SORCE/NASA [5] satellite's data for the same period

Table 1
Stations for the solar irradiation measurements.

Station	Geographical coordinates			Climate	Period
	Lat.	Long.	H(m)		
Água Branca	9°15′15″S	37°56′15″W	593	Tropical – Semi-arid	Jan–Nov 2008
Santana do Ipanema	9°22′31″S	37°13′54″W	279	Tropical – Semi-arid	Jan–Dec 2008
Palmeira dos Índios	9°24′20″S	36°39′23″W	328	Tropical – Semi-arid	Jan–Nov 2008
Maceió	9°28′29″S	35°49′44″W	127	Tropical – Maritime	Jan-Set 2008
Laje	9°00′35″S	36°03′30″W	256	Tropical – Semi-arid	Jan–Dec 2008
Pão de Açúcar	9°44′54″S	37°26′12″W	19	Tropical – Semi-arid	Jan–Dec 2008
Arapiraca	9°45′09″S	36°39′40″W	264	Tropical – Semi-arid	Jan–Dec 2008
Coruripe	10°07′32″S	35°49′44″W	16	Tropical – Maritime	Jan–Dec 2008

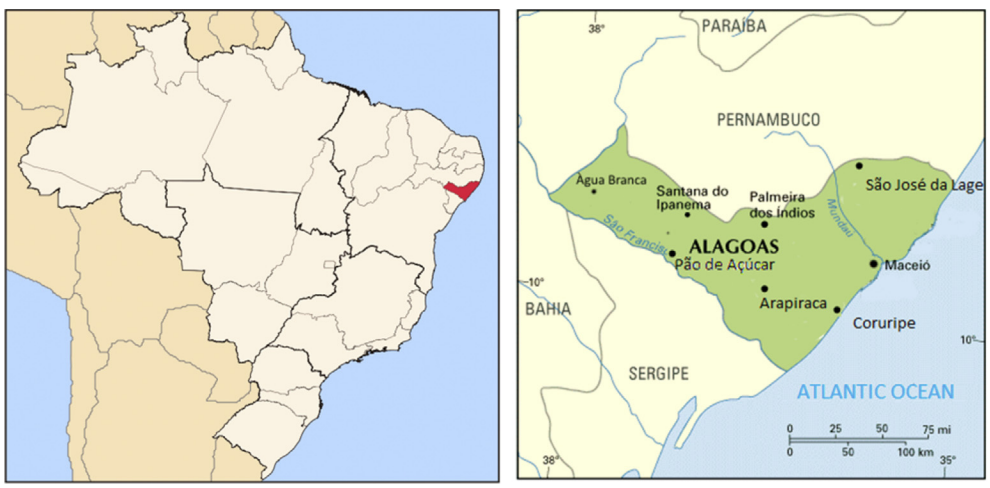

Fig. 1. Locations of the state of Alagoas and the solarimetric stations: A-Coruripe, B-Água Branca, C-Santana do Ipanema, D-Palmeira dos Índios, E-Maceió, F-São José da Laje, G-Pão de Açúcar and H-Arapiraca.

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