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Solar energy resource assessment in Mexican states along the Gulf of Mexico

Q. Hernández-Escobedo [a], E. Rodríguez-García [c], R. Saldaña-Flores [b], A. Fernández-García [e], F. Manzano-Agugliaro [d,f,*]

[a] Facultad de Ingeniería, Universidad Veracruzana, Campus Coatzacoalcos, Avenida Universidad Veracruzana km. 7.5, CP 96536 Col. Santa Isabel, Coatzacoalcos, Veracruz, Mexico
[b] Instituto de Investigaciones Eléctricas, Reforma 113, Col. Palmira, C.P. 62490 Cuernavaca, Morelos, Mexico
[c] Centro de Investigaciones en Recursos Energéticos y Sustentables, Universidad Veracruzana, Campus Coatzacoalcos, Avenida Universidad Veracruzana km. 7.5, CP 96536, Col. Santa Isabel, Coatzacoalcos, Veracruz, Mexico
[d] BITAL (Research Center on Agricultural and Food Biotechnology), CEIA3, University of Almeria, La Cañada de San Urbano, E-04120 Almería, Spain
[e] Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), Plataforma Solar de Almería, Ctra. Senés, km. 4, E04200 Tabernas, Almería, Spain
[f] Department of Engineering, University of Almería, La Cañada de San Urbano, E04120 Almería, Spain

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ABSTRACT

The development of renewable energy has increased over the past few years due to the high cost of fossil fuels and our great dependence on them. Solar energy has been evaluated in the majority of developed countries. Mexico is known to possess large quantities of renewable energy resources, for example, approximately 6000 MW of wind energy resources. Nevertheless, solar energy is not sufficiently developed in Mexico. In this work, the global solar resources in Mexican states along the Gulf of Mexico were assessed. The data used in the analysis were obtained from the Automatic Meteorological Stations (AMEs) of the National Meteorological Service of Mexico (NMS) every 10 min over a period of 10 years, as well as from the Surface Meteorology and Solar Energy (SMSE) of the National Aeronautics and Space Administration (NASA) every month over 22 years. AMEs and SMSE validation data were compared to calculate their determination coefficient, R^2, which was above 90%. A total of 13 maps generated by a Geographic Information System (GIS), one per month, and annually averaged global solar resources were used to determine the areas and the periods of the year with the greatest global solar energy resources. According to the results obtained in this study, the highest amount of solar energy, i.e., greater than 6.22 kWh/m^2/day, was registered on July in the state of Tamaulipas. Based on the average annual energy map, the southern region of Veracruz State registered the largest resource, i.e., greater than 5.03 kWh/m^2/day. From the foregoing analysis, the primary conclusion arrived at in the present work is that solar energy has significant potential for complementing energetic requirements in Mexican states along the Gulf of Mexico. It is recommended that the government adopt policies supporting and promoting the utilization of solar energy to maintain fossil fuel reserves and to reduce greenhouse gases.

Contents

1. Introduction

It is well-known that burning fossil fuels (coal, oil, and natural gas) generates pollutant gases (SO_2, CO, NO_X, HC, and CO_2) that

* Corresponding author.
E-mail address: fmanzano@ual.es (F. Manzano-Agugliaro).

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Nomenclature

Abbreviations

AMEs	Automatic Meteorological Stations
GIS	Geographic Information System
NASA	National Aeronautics and Space Administration
NMS	National Meteorological Service of Mexico
SMSE	Surface Meteorology and Solar Energy
ARIMA	Autoregressive Integrated Moving Average

Symbol

R^2	coefficient of determination
$\hat{\beta}_0$	squared minimum of the ordinate at the origin
$\hat{\beta}_1$	slope of the straight line
$Z(S_i)$	value measured at position i
λ_i	unknown weight for the value measured at position i
S_0	predicted location
n	number of measured values

cause environmental pollution problems [1]. The development of renewable energies has increased over the past few years due to the high price of fossil fuels and our great dependence on them [2]. Solar energy is considered one of the most promising alternative sources of energy for avoiding the dependency on fossil energy resources [3,4]. In addition to being free, clean, and abundant, the evaluation of solar energy resources is especially important because of the high cost and the degradation of the environment caused by the use of fossil fuels [5]. For example, in 2009, 43% of CO_2 emissions from fuel combustion worldwide came from coal, 37% from oil, and 20% from gas [6].

Solar energy has gained the attention of many industries and areas of application in recent years [7]. Information about the characteristics of solar energy throughout the world plays an important role in the study, planning, and design of applications of this energy [8,9]. Therefore, data on solar radiation over the surface of the Earth are essential for studying and designing systems utilizing energy from the sun [10].

Solar energy received above the atmosphere (that is, the radiation that would be received on the Earth's surface in the absence of the atmosphere) is called extraterrestrial solar energy, whereas solar energy that is received below the atmosphere is called global or total solar energy [11]. Global solar radiation is the sum of the beam or direct radiation and the diffuse solar radiation on a surface, where the former is radiation received from the sun without having been scattered by the atmosphere and the latter is radiation received from

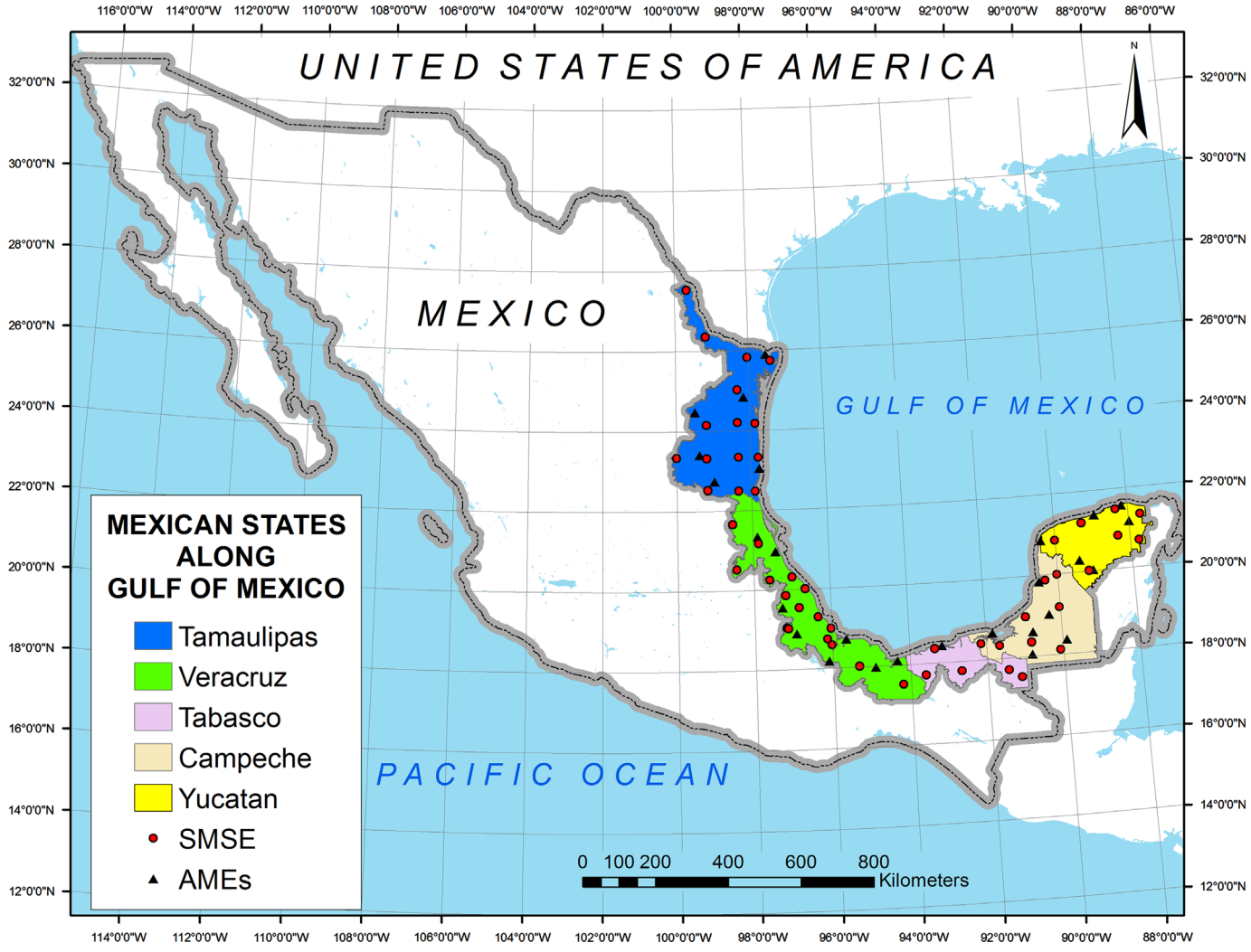

Fig. 1. Geographical locations of the stations employed in the Gulf of Mexico study.