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Measurement and comparison of diffuse solar irradiance models on inclined surfaces in Valladolid (Spain)

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Abstract

This paper presents the performance of 10 arithmetic models used to estimate diffuse solar irradiance on inclined surfaces in a comparative study with actual data readings made available on an hourly and a daily basis. The data readings have been taken from a south facing surface inclined at 42° in an area at some distance from the provincial capital in the Spanish province of Valladolid. In order to confirm the results, three statistical parameters have been used in the study; root mean square error (RMSE), mean bias error (MBE) and Stone's *t*-statistic. The results obtained favour the Muneer model, followed by the Reindl model, for hourly as well as for daily values. The Temps–Coulson model gives rise to great discrepancies with respect to the values measured. The results for the Perez model are not good due to the use of parameters that are not specifically calculated for the area in this study, which underlines the need to take an area's features into account so that predictions for diffuse irradiance measured on inclined surfaces may be as accurate as possible.

Keywords: Solar radiation; Diffuse irradiance; Tilted surfaces

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Nomenclature

B_{h0}	hourly direct horizontal irradiance ($kJ\,m^{-2}h^{-1}$)
B_{hb}	hourly direct inclined irradiance ($kJ\,m^{-2}h^{-1}$)
$^*D_{h0}$	hourly diffuse horizontal irradiance ($kJ\,m^{-2}h^{-1}$)
D_{hb}	hourly diffuse inclined irradiance ($kJ\,m^{-2}h^{-1}$)
G_{h0}	global irradiance on horizontal surface ($kJ\,m^{-2}h^{-1}$)
I_{0h}	extraterrestrial irradiance on horizontal surface ($kJ\,m^{-2}h^{-1}$)
K	global hourly and horizontal clearness indices (G_{h0}/I_{0h})
K_i	global clearness index—10 min (G_{0i}/I_{0i})
MBE	mean bias error
m	mass of air
N_{pt}	cloud cover factor
R_b	direct radiation conversion factor
R_{di}	isotropic configuration factor of sky
RMSE	root mean square error
r	radius of diffuse sensor shadow band

Greek symbols

β	inclination angle of sensors (rad)
ε	clearness index (Perez model)
ε'	anisotrophy factor (Perez model)
θ	angle of incidence on inclined surface (rad)
θ_z	zenith angle (rad)

1. Introduction

The majority of practical applications of solar energy are systems based on thermal or photovoltaic processes. An understanding of the global and diffuse constituents of solar irradiance incident on inclined surfaces is essential in the design of such systems. Different models need to be developed that allow radiation values to be known or predicted for proper optimization of solar power installations.

The objective of this study is to compare 10 diffuse irradiance models on inclined surfaces. Each model was published at a different point in time, and all of them have been satisfactorily tried and tested. Some of them are over 20 years old and are still being used at present as models with which to modify or establish new coefficients to relate different climatic variables. Others, which are more recent, are also currently being analysed and modified, so as to arrive at increasingly accurate results when predicting values for the solar irradiance on inclined surfaces.

It is important to highlight that none of the models being used for the study have been defined to calculate diffuse irradiance itself. All of the authors have published their models to predict values for the global irradiance incident on inclined surfaces as a sum of three components: direct,