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SOLAR ENERGY RESOURCES AT SOUTH REGION OF BRAZIL

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ABSTRACT

The Center for Weather Forecast and Climate Studies at the Brazilian National Institute for Space Research, Ministry of Science and Technology - CPTEC/INP-MCT, have installed throughout Brazilian territory several sites to acquired solar irradiation data used to assess the renewable energy potential of Brazil as part of SONDA project (www.cptec.inpe.br/sonda/). One of ground sites is located at the Southern Space Observatory–SSO/CRS/CIE/INPE–MCT, (29 ºS; 53ºW), in São Martinho da Serra, RS, South of Brazil, where diffuse and global solar irradiation are measured by CM 22 and CM21 Pyrhanometers), direct solar radiation are measured by Pyrheliometer NIP and opaque and thin cloudiness fractions were esteemed by a Total Sky Imager TSI-440 (YES, Inc). Our concern is with the fact that the current world energy scenery, characterized by petroleum sources exhaustion and environmental concerns, point out to the use of clean and renewable energy sources such as the solar energy. This work aims to the evaluation of the solar energy resource by using stochastic models relating the cloud cover fraction and solar radiation parameters such as diffuse-to-direct-beam ratio (DDB), diffuse-to-global solar irradiation ratio (K), diffuse-to-TOA irradiation ratio (K), global-to-TOA irradiation ratio (KT), and direct-beam-to-TOA irradiation ratio (DB-TOA) measured with the SONDA Project, where TOA is the total irradiation that reach the atmosphere. Only data collected for zenithal solar angle (SZA) lesser than 75 deg for the period between September/2005 to August/2006 were used. The ground data were averaged for fifteen minutes intervals in order to reduce the influence of high frequency variability of cloud cover. It was observed low correlation around 0.55) among the KD and DDB parameters and the cloud cover. Better correlation (over 0.90) were obtained for K and DB-TOA parameters. The statistic deviations RMSE (23-28%) and MBE (0.3–5%) were calculated to validate and compare the models performance. The results showed more influence from opaque cloudiness on radiation scattering. The estimates provided by these empirical models were compared to the Brazilian Atlas for Solar Energy published in 2007.

INTRODUCTION

➢The current world energy scenery, characterized by petroleum sources exhaustion and environmental concerns, point out to the development of new efficient technologies for make use of clean and renewable energy sources.

➢ To support this policies, the wind and solar energy assessment and forecast can be achieved through ground data and radiative transfer models.

➢The cloudiness is the main impact factor on solar irradiation at surface, and the major cause of deviations on estimated values [Martins and Pereira, 2007].

➢ This paper aims at the evaluation of solar energy resources at South of Brazil by using empirical models relating the cloud cover fraction and solar radiation parameters measured at Southern Spatial Observatory – SSO/CRS/CIE/INPE – MCT.

➢ Another goal is to study the influence of thin and opaque cloudiness on the fraction of different components of the solar radiation that reaches the ground.

Figure 1 - SONDA reference station installed at the Southern Space Observatory – SSO/CRS/CIE/INPE – MCT.

METHODOLOGY

➢ One of the reference ground sites of the SONDA network (Figure 1) is located at the Southern Space Observatory – SSO/CRS/CIE/INPE – MCT, in São Martinho da Serra, Brazil.

➢ Global, Diffuse, and Direct Solar Irradiation was measured respectively by *CM21 and CM 22 Pyrhanometers (Kipp & Zonen),* and Pyrheliometer NIP while opaque and thin cloudiness fractions were esteemed by a *Total Sky Imager TSI-440 (YES, Inc).*

➢The *TSI-440* has a colored camera to capture sky image each 15 minutes. The pixels are evaluated by the *TSI Manager Software* and classified as thin and opaque clouds.

➢ It was analyzed about 12000 *TSI-440* data collected for zenithal solar angle (SZA) lesser than 75deg. between September/2005 to August/2006.

➢ It was calculated the diffuse-to-direct-beam ratio (DDB), diffuse-to-global solar irradiation ratio (K), diffuse-to-TOA irradiation ratio (KD), and global-to-TOA irradiation ratio (KT), and direct-beam-to-TOA irradiation ratio (DB-TOA) radiation parameters. Where TOA is the solar global irradiation at top of atmosphere [Iqbal,1983].

➢ The solar parameters were analyzed as function of thin, opaque, and total cloudiness fractions and separated into development of empirical models group and the models statistic validation group.

➢ The empirical models were developed by polynomial (PR) and multiple linear regression (MLR) and validated by the Mean Bias Error (MBE) and Roots Mean Square Error (RMSE) calculation.

RESULTS

➢ The K and DB-TOA parameters behavior as function of the total cloud cover are showed respectively in Figures 2 and 3. We can notice that K increase and DB-TOA decrease with cloud cover raise, in both cases, due of the solar irradiation scattering and reflection phenomena.

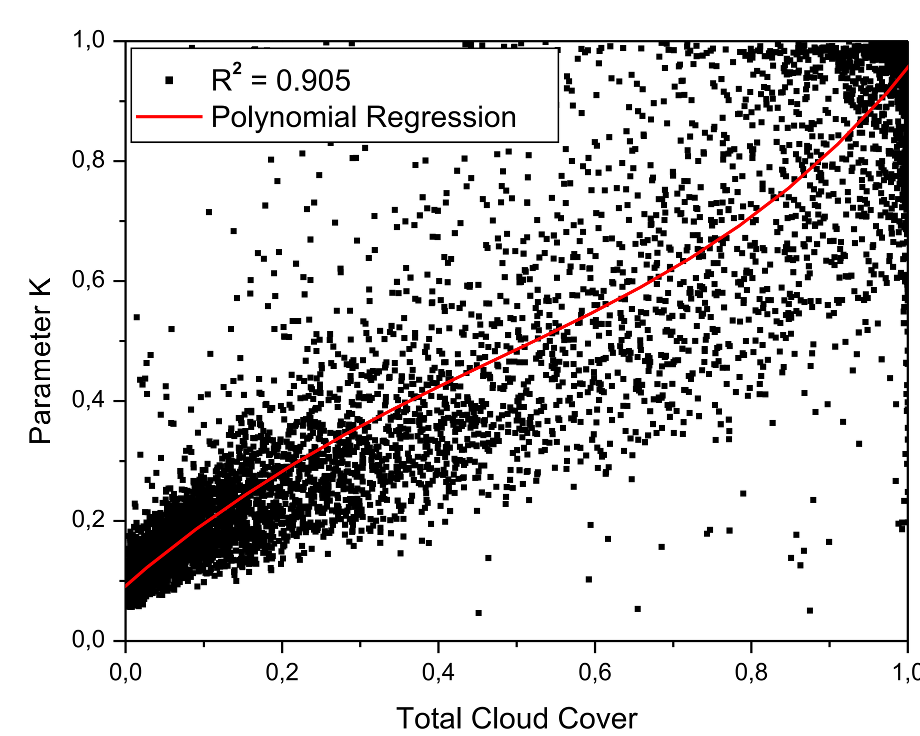

Figure 2 – Solar Radiation Parameter K as function of total cloud cover measured at Southern Space Observatory

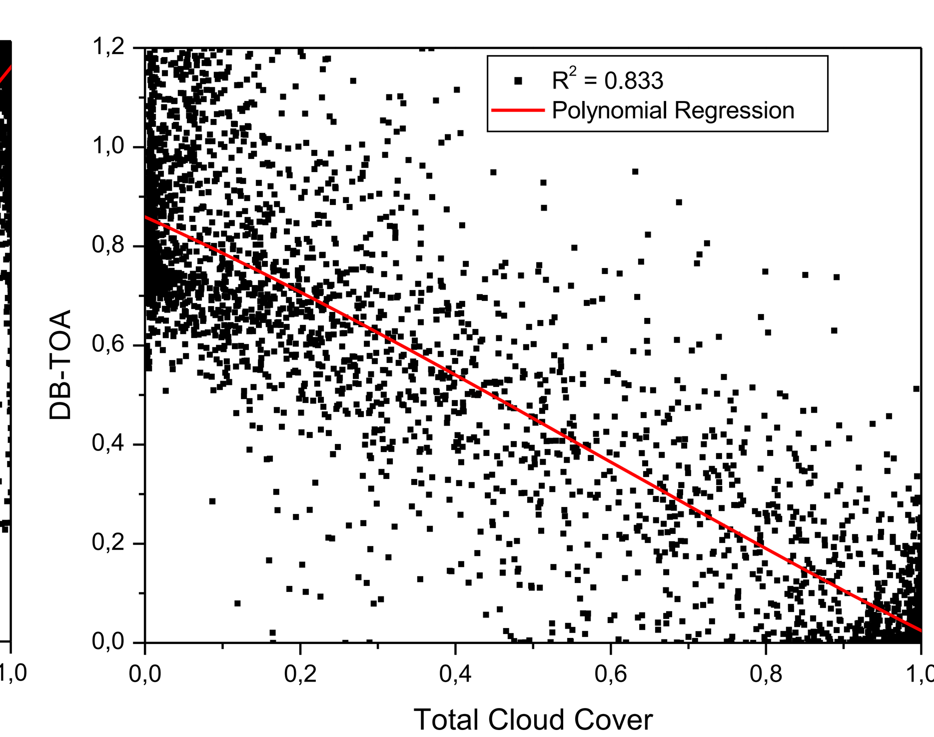

Figure 3 – Solar Radiation Parameter DB-TOA as function of total cloud cover measured at Southern Space Observatory

➢ The correlations factors between the solar irradiation parameters with total, opaque and thin cloudiness fractions in the whole period are presented are showed at the Table 1.

Table 1 – Correlation factors between solar irradiation parameters and cloudiness fractions

Cloud Fraction	KT	KD	K	DB-TOA	DDB
Thin	-0,349	0,192	0,352	- 0,352	0,134
Opaque	-0,791	0,511	0,92	-0,877	0,616
Total	-0,835	0,529	0,951	-0,909	0,596

➢ The opaque cloud fraction showed more influence in the solar radiation. However the thin fraction has participated on the total cloud cover amount, contributing to obtaining the best correlations.

➢ In the validation step, according to the Table 2, the empirical models developed showed medium statistic deviations: MBE (0,02-0,665 %) and RMSE (22-35%).

Table 2. Statistics Deviations and Correlation Coefficients for the empirical models developed.

Empirical Model	R²	MBE (%)	RMSE(%)
KT (MLR)	0,698	0,665	26,63
KT(PR)	0,716	0,635	25,81
K (MLR)	0,901	-0,606	22,17
K (PR)	0,905	-0.653	21,94
DB-TOA (MLR)	0,833	0,02	35,30
DB-TOA (PR)	0,833	0,02	35,34

CONCLUSION

➢ It was observed medium and high correlations between the cloud cover data available and solar irradiation measurements, that can contribute to energetic models improvements.

➢ Nevertheless, due the complexity of interactions clouds – solar radiation, great results are achieved observing others cloud properties such optical depth, cloud type, amount, and height.

➢ A longer temporal data series is necessary to get more reliable empirical models. The influence of cloudiness on other components of the global solar irradiation should be made in near future.

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