Predicting Global Solar Radiation on Horizontal Surface

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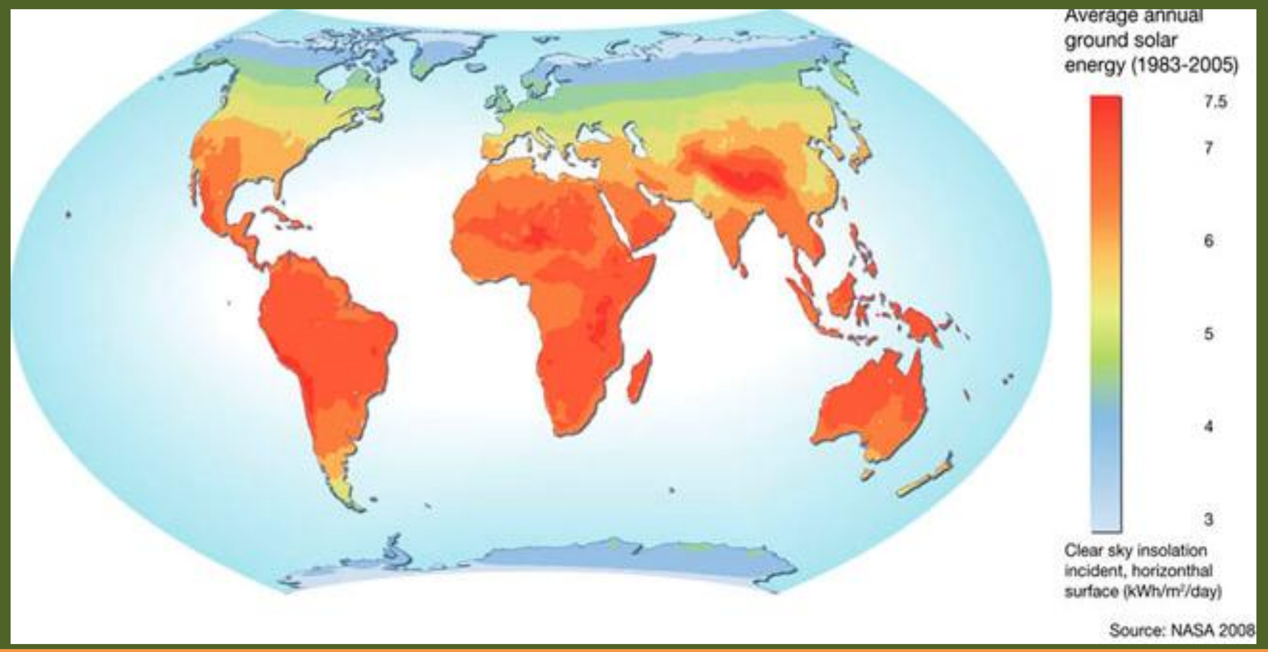
Introduction

Energy from sun (i.e., solar energy) is the most abundant energy (Figure) resource on earth (the total energy consumed by all human activities = solar energy falling on earth surface in an hour)(IEA, 2010). That energy is utilized by Photovoltaic (PV) Cells to produce electricity. The precise estimation of solar energy falling on horizontal surface can help designing an efficient and reliable PV system. To support PV cell design in remote places, here we have developed a model capable of predicting solar radiation falling on a horizontal surface. The model can be useful for remote places, where input data required for calculating solar energy are rare.



Objectives

The objectives of this study are to develop a model for calculating solar radiation, and verify the predictions in clear and cloudy sky conditions.

Methods

Here a transmission function $T_{f,ij}$, which estimate global solar radiation was developed, which is described elsewhere (Pandey et al., 2012). The global solar radiation was estimated by multiplying the $T_{f,ij}$ with solar insolation (I_0).

$$G_{h,ij} = T_{f,ij} \times I_0 \qquad \text{.......(1)}$$

$$T_{f,ij} = (R_i \times R_j) \qquad \text{.......(2)}$$

$$R_i = Y_d + \frac{a_d}{1+\left(\frac{X_i - X_{d0}}{b_d}\right)^2} \qquad \text{.......(3)}$$

$$R_j = Y_h + \frac{a_h}{1+\left(\frac{X_j - X_{h0}}{b_h}\right)^2} \qquad \text{.......(4)}$$

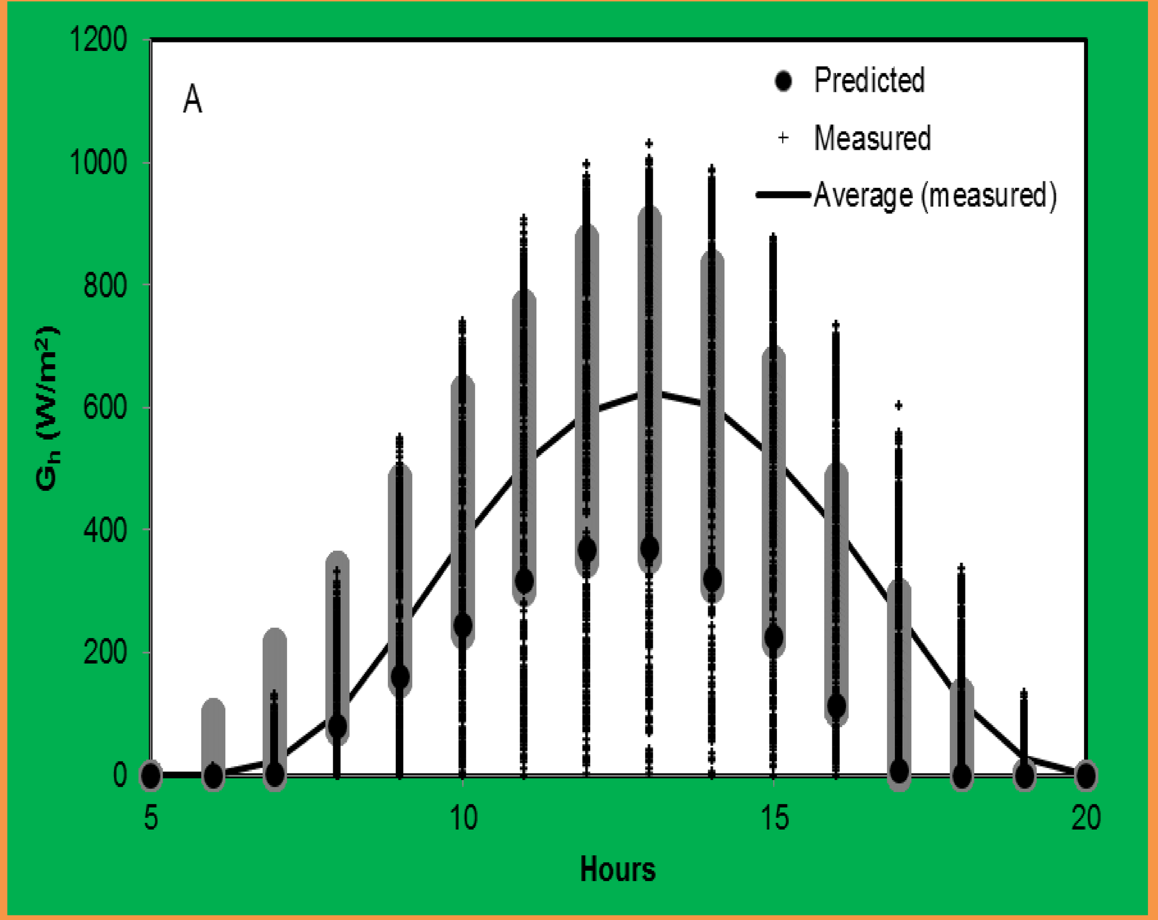
where $G_{h,ij}$ (eq. 1) is in W/m^2; I_0 is in W/m^2 and $T_{f,ij}$ (eq. 2) is an unitless transmission function which calculates solar radiation values for i^{th} day of a year and j^{th} hour of i^{th} day. Values of i varies from 1 to 365 (Julian day) and j varies from 0 to 23 (hr) for each day. R_i (eq. 3) is the transmission function value for i^{th} day and R_j (eq. 4) is the transmission function values for j^{th} hour. Y_d and Y_h are constants which control the starting point of transmission functions; a_d and a_h are constants which control the peak of functions; and b_d and b_h are constants that control the spread of data. X_i is Julian day, and X_j is the hours of the day (0 - 23 hr). X_{d0} and X_{h0} are constants that control the locations of the peaks (Pandey et al., 2012).

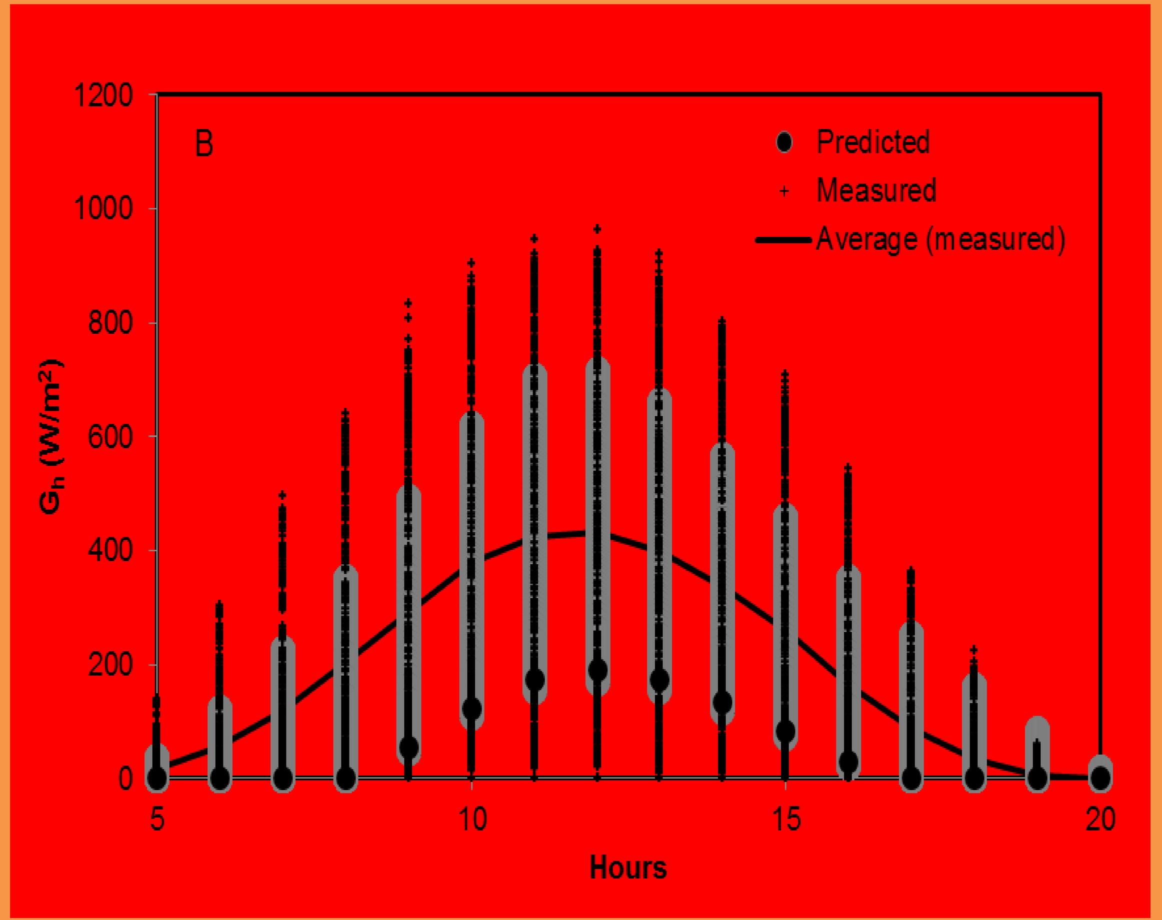
Study Area

The model was implemented in two sites: 1) Mueller Municipal Airport, Austin, Texas; and 2) Boeing Field, Seattle, Washington. The location in Austin is located at 30° 16′ 2″ N, 97° 45′ 50″ W. It has a humid subtropical climate and receives an annual average of 853 mm of rainfall. Austin is sunny about 60 - 65% of the year. Most rain occurs during the winter season but the peak rainfall occurs in May (NOAA, 2012). The location in Seattle is located at 47° 36′ 35″ N, 122° 19′ 59″ W. It has a temperate, rainy climate. December is wettest month but rainfall occurs very frequently throughout the year (about 150 days per year) with an annual average of 942 mm. About 201 days are cloudy and 93 days are partly cloudy (NOAA, 2012). Measured solar radiation for the two sites was obtained from National Solar Radiation Database (NSRDB), USA. Hourly measured data (8760 hours for a year) were used for comparison with predicted data.

Results and Discussion

Figures show predicted and measured global solar radiation. Figure A (left) shows predicted, measured, and average measured radiation at Austin, Texas. Figure B (right) shows predicted, measured, and average measured radiation at Seattle, Washington.





The average hourly global solar radiation prediction for Seattle (R^2 = 0.99) were better than Austin (R^2 = 0.94), however, for both locations predictions were well matched with measured global solar radiation. We anticipate that the model performance may vary by locations (depending on clear and cloudy sky conditions), therefore, the validation of the model for the location of interest would be required.

Conclusions and Recommendations

Here a transmission function $T_{f,ij}$, which estimate global solar radiation was proposed, and validated. The predicted and measured data matched well. Further exploiting this model for multiple clear and cloudy sky conditions will help improving predictions.

References: International Energy Agency (IEA) (2010) Technology roadmap for photovoltaic energy. IEA Publications, 9 rue de la Fédération, 75739 Paris Cedex; accessed on 4.15.2013; www.iea.org). Pandey, P.K., Soupir, M.L. (2012). A new method to estimate average hourly global solar radiation on horizontal surface. Atmospheric research, 114-115, 83 – 90. National Oceanic and Atmospheric Administration (NOAA) (2012). http://www.noaa.gov/