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A model for calculating daily near infrared solar radiation

W Thongrasmee, K Tohsing and S Janjai

Laboratory of Tropical Atmospheric Physics, Department of Physics, Faculty of Science, Silpakorn University, Muang, Nakhon Pathom 73000, Thailand

E-mail: korntip.tohsing@gmail.com

Abstract. In this work, a semi-empirical model for calculating daily global near infrared solar radiation (NIR) was developed. The model is written in the form of the ratio of daily global NIR (H_{NIR}) to daily global broadband solar radiation (H) as an empirical function of atmospheric parameters influencing H_{NIR}/H namely, precipitable water (w), total ozone column (O_3), aerosol optical depth (AOD) and cloud index (n). A 5-year period (2009-2013) data of H_{NIR}, H, w, O_3, AOD and n obtained from 4 meteorological stations situated in the main regions of Thailand were used to calculate the empirical coefficients of the model. This model was tested against an independent measured data set. It is found that H_{NIR} calculated from the model and that from the measurement are in good agreement, with the difference in terms of root mean square error of 7.7% and mean bias error of 5.3%.

1. Introduction

The solar radiation at earth's surface consists of ultraviolet radiation (0.29-0.40 µm), visible radiation (0.4-0.7µm) and near infrared radiation (0.7-3.0 µm) [1]. Near infrared radiation (NIR) contributes about 52% of total energy from sun and it affects temperature of the earth's atmosphere and evapotranspiration in plants. NIR data are usually required for the simulation of plant growth in the study of biomass production [2, 3]. In general NIR on the earth's surface varies with locations and atmospheric conditions. In principle, the amount of NIR incident on the earth's surface should be obtained from the measurements. However, the measurements of NIR are very scarce due to high equipment and operational costs. An alternative to obtain NIR data is to use modeling approach. Although, in the past decade, some researchers have proposed model to compute NIR [4, 5], these models express the ratio of NIR to broadband global radiation as constant values, making their applications being limited. Therefore, the objective of this work is to develop a more general semi-empirical NIR model in which atmospheric parameters affecting NIR are taken into account.

2. Methodology

In order to achieve the objective of this work, various tasks, namely preparation of data, formulation of the model and model validation were carried out. The details for each task are described as follows.

2.1 Preparation of data

To develop the model for calculating global NIR from global broadband solar radiation (BR) and atmospheric parameters, it is necessary to have global NIR, global BR and related atmospheric data. In this work, data on global NIR and global BR measured at 4 meteorological stations, namely Chiang

Mai (CM, 18.78°N, 98.98°E), Ubon Ratchathani (UB, 15.25°N, 104.87°E), Nakhon Pathom (NP, 13.82°N, 100.04°E) and Songkla (SK, 7.20°N, 100.04°E) during the year 2009 – 2014 were collected. Additionally, data on atmospheric parameters, namely precipitable water (w), aerosol optical depth (AOD), total ozone column (O_3) and cloud index (n) at the locations of these stations for the same period were also prepared. w and AOD were provided by AERONET of NASA [6, 7]. O_3 was obtained from OMI/AURA satellite and cloud index (n) was derived from MTSAT1R satellite using the algorithm proposed by Cano et al. [8].

2.2 Formulation of the model

The model for calculating NIR proposed in this work considers the radiative properties of clouds, aerosols, water vapour and ozone. Clouds absorb significantly solar radiation in the NIR band. Aerosols scatter more solar radiation in the short wavelength band than that in the NIR band. Water vapour also absorbs significantly in the NIR band. For ozone, it absorbs solar radiation in the visible wavelengths which is part of BR and there is no absorption by ozone in NIR band. With the difference in effects of these atmosphere constituents on NIR and BR, the model for calculating NIR in the form of the ratio of NIR to BR is proposed as follows.

$$\frac{H_{NIR}}{H_G} = a_0 + a_1 n + a_2 O_3 + a_3 AOD + a_4 w \qquad (1)$$

where H_{NIR} is daily near infrared irradiation (MJ m^{-2} day^{-1}), H_G is daily global irradiation (MJ m^{-2} day^{-1}), n is cloud index (-), O_3 is total ozone column (cm.) AOD   is aerosol optical depth at 550 nm (-), w is precipitable water (cm.) and a_0, a_1, a_2, a_3 and a_4 are empirical coefficients. To obtain the coefficients, equation (1) was fitted with the corresponding data collected from the four stations encompassing a period: 2009 - 2013.

2.3 Model validation

Although, the proposed model was rigorously formulated, it is necessary to validate its performance. To accomplish this, the model was used to calculate NIR at four stations using input data encompassing the period: January - December, 2014. NIR calculated from the model was compared to that obtained from the measurements. As these data were not involved in the formulation of the model, they are independent data. Therefore these data has merit in the validation.

3. Results and discussion

After fitted equation (1) with the corresponding data, the values of the empirical coefficients were obtained and the proposed model with the values of the coefficients can be written as:

$$\frac{H_{NIR}}{H_G} = 0.435680 - 0.037650n + 0.000424O_3 + 0.021494AOD - 0.015857w \qquad (2)$$

For the validation results, the comparison between NIR calculated from the model (equation (2)) and that obtained from the measurement is shown in figure 1.
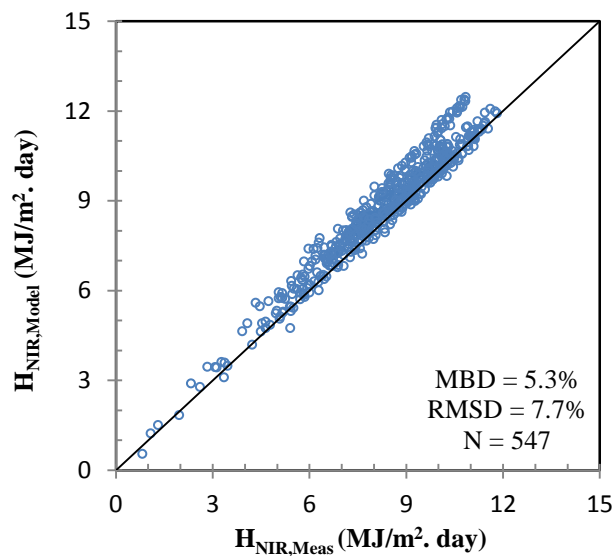
Figure 1. Comparison between NIR from the model ($H_{NIR,Model}$) and that from the measurement ($H_{NIR,Meas}$). (RMSD is root mean square difference, MBD is mean bias difference and N is total number of data points.)

From figure 1, it is observed that most of the calculated NIR values and measured NIR values are in good agreement, with the discrepancy in terms of root mean square error (RMSD) of 7.7 % and mean bias error (MBD) of 5.3 %.

4. Conclusions

In this work, a model for estimating daily NIR in Thailand has been developed. The model expresses the ratio of NIR to global solar radiation as an empirical function of cloud index, total ozone column, aerosol optical depth and precipitable water. The model performed well when tested against independent data.

Acknowledgements

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