A study of measuring and estimating for in-plane irradiation using minute horizontal Global Irradiation

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ABSTRACT

To propose a formula for calculating irradiation onto an in-plane surface from measured data on the tilt angle, detailed examination has been made by using data obtained for every one minute. The adoption of clearness index has make time-independent analysis available. By evaluating the moving averages of time-series data, an information of weather conditon could be acquired. This work presented in a new calculating model for estimating irradiance onto an in-plane surface. The input parameter for this model is global irradiation sampled with 1 minute, and no other parameter is needed. This model will offer a guide to observation systems that one-minute global irradiation data should be measured surely.

1. Introduction

It is necessary to separate diffuse irradiation and direct irradiation from horizontal global irradiation in order to estimate in-plane irradiation where in-plane irradiation itself is not been measured. Some models for estimating the diffuse irradiation from the global irradiation by using relationship between diffuse and circumsolar irradiance have been already proposed by many authors and are often used[1]. However, almost such models have errors that is caused by variable sky condition in their estimation at partially cloudy and fluctuation. In this study, the author's purpose is to make a simple model for estimating the diffuse fraction, which model use time series of minute global irradiation data

2. Approach

Global irradiation and diffuse irradiation have been monitored with EKO MS801 pyranometer and EKO pyranometer with co-operated shadow-ball in our University(35° 696'N, 139° 52'E). They measured solar radiation with time interval of one minute. Figure 1 illustrates a relationship between diffuse component ratios (diffuse irradiance/global irradiance) and clearness indices (global irradiance/extraterrestrial irradiance).

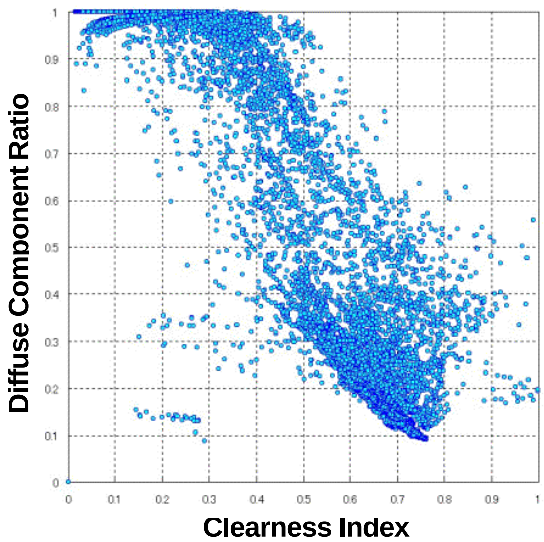

Figure 1: Relationship between Diffuse Component Ratios and clearness indices

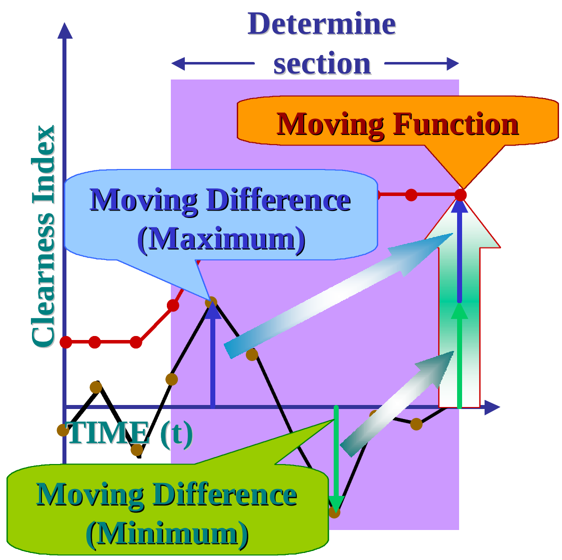

Figure 2: How to calculate the Moving-Function From the Clearness Indices.

There are high scatterations each other. It is difficult to make estimative model for diffuse component ratio. In this investigation, we have 4-classification for weather to make the estimative model and the "Moving Function (MF)" which is determined by "Moving Average (MA)" and "Moving Difference (MD)".

To obtain an information of weather condition, the "Moving Function (MF)" was defined. At first, we defined the "Moving Average (MA)". MA is described for clearness index *Z (t)* as Equation (1).

$$MA(t) = \frac{1}{DS+1}\sum_{s=0}^{DS} Z(t-s) \qquad \textbf{(1)}$$

Z (t): Clearness Index DS: Determine Section

"Moving Difference (MD)" is the difference from MA at that time. Then, total number of Maximum MD and Minimum MD is Moving Function (MF) in the Determine Section (5 minutes).

The conditions of "Clear" and "Cloudy" are so stable that we can use only clearness indices to separate the classes. The other party, "Partially cloudy" and "Fluctuation" are not so stable that we should use the "Moving Function (MF)" additionally. Our model is based on the fact that time-series-MF provides the information of weather condition. Measuring the global irradiance data that is monitored at one-minute intervals, we can estimate the diffuse radiation at the same time by using that model (named "Time-series-model").

3. Results

We used Residual Number, one is Root Mean Square Error (RMSE(2)) for error from Measured and the other is Mean-Bias-Error (MBE(3)) for bias error from measured., to assess Time-series-model.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(I_E - I_M)^2}{n}} \qquad \textbf{(2)}$$

$$MBE = \frac{\sum_{i=1}^{n}(I_E - I_M)}{n} \qquad \textbf{(3)}$$

I_E: estimated value, I_M: measured value

we compared irradiance estimated Time series model to Erbs model about In-plane and Diffuse Hourly irradiance at every sky condition. Figure 3 shows comparison of Hourly In-plane Irradiance between measured and estimated irradiance. All of times, estimated value using Time-series-model is proximate to measured value. Table 1 shows comparison of Time series model and Erbs model using Residual number about estimating Hourly Diffuse Irradiance. All of conditions, it is showed that Time series model has high quality to separate the Hourly Global Irradiance to Hourly Diffuse Irradiance. While estimating the Hourly In-plane Irradiance, Time-series-model is better than Erbs-model (Table 2) at all condition.

4. Conclusion

It is showed that Time series model is good for estimating Diffuse and In-plane Hourly Irradiance. Particulally, estimated value using Time-series-model is proximate to measured value everytime.In addition, compared Time series model to Erbs model with Residual number, it is showed that Time series model has high quality to separate the Hourly Global Irradiance to Hourly Diffuse Irradiance. As well as Hourly In-plane Irradiance, Time series model is better than Erbs-model at all condition.

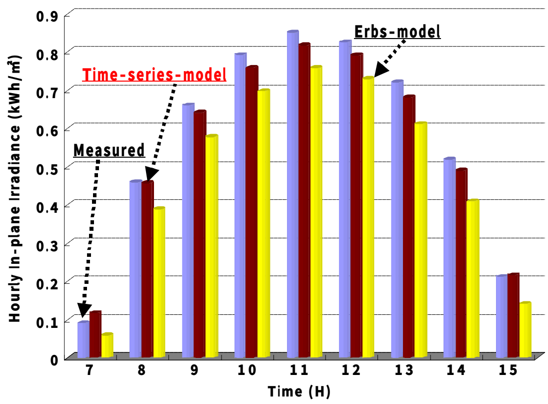

Figure 3: Comparison of Measured and Calculated. "Clear"

Table 1: Comparison of T.model and E.model about H.D.I.

	Clear	Cloudy	P.Cloudy	Fluctuation
T.(RMSE)	**0.003**	**0.0002**	**0.016**	**0.037**
T.(MBE)	**-0.001**	**-0.0001**	**0.001**	**-0.019**
E.(RMSE)	**0.062**	**0.002**	**0.043**	**0.043**
E.(MBE)	**0.058**	**-0.001**	**0.037**	**0.024**

Table 2: Comparison of T.model and E.model about H.I.I.

	Clear	Cloudy	P.Cloudy	Fluctuation
T.(RMSE)	**0.03**	**0.003**	**0.032**	**0.041**
T.(MBE)	**-0.08**	**0.003**	**-0.017**	**-0.026**
E.(RMSE)	**0.088**	**0.004**	**0.060**	**0.077**
E.(MBE)	**-0.084**	**0.004**	**-0.055**	**-0.061**

T.:Time-series-model, E.:Erbs-model, P.:Partially,
H.D.I.:Hourly Diffuse Irradiance, H.I.I.:Hourly In-plane Irradiance

5. References

1)D.G.Erbs, S.A.Klein, J.A.Duffie; ESTIMATION OF THE DIFFUSE RADIATION FRACTION FOR HOURLY AND MONTHLY-AVERAGE GLOBAL RADIATION, *Solar Energy* Vol.28, No.4, pp.293-302, 1982.