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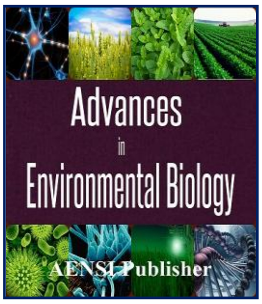

Variation Over Time of the Du Mortier Calibration Algorithm for Ground-Based Spectrometer

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ABSTRACT

Background: Having a stable and steady calibration constants increases the likelihood of a spectrometer to perform as expected over a reasonable period of time. The purpose of this paper is to study the variation over time of the Du Mortier calibration algorithm used in a spectrometer for atmospheric condition measurement. This is carried out over a course of six months and the measurements were taken for every minute intervals from 8.30am to 4.30pm in three locations in Kota Kinabalu. By using the improved Langley method, monthly calibration constants for eight wavelengths were determined for Du Mortier model. Results shows that there were statistically significant differences between mean calibration constants when comparing the selected months. However, if only wavelengths of 460nm, 500nm, 540nm, 580nm and 620nm are taken into account, the results say otherwise.

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INTRODUCTION

Malaysian government is enhancing the utilization of renewable energy and venturing its possibility as the sole energy provider in Malaysia. Solar energy have the highest potential to become primary sources of renewable energy in Malaysia because it is located in tropics and receives abundant sunlight throughout the year [6] with sunshine duration greater than 2200 hour per year [3]. Sabah can achieved of about 6.027 kWh/m^2 per year [4]. Therefore, this advantage should be fully utilised as an alternative electric power generation in Sabah. By assessing solar radiation spectrum, it can help us to identify solar intensity in particular location in Sabah and by doing so, it help to model the spectrum references. This ground-based measurements data is obtained using a spectrometer. However, to have a reliable data, the spectrometer must be calibrated. This study is carried out to evaluate the consistency of calibration constant using Du Mortier Method. Jackson *et al.* [10] has developed a new langley calibration algorithm which combined the clear-sky condition, Perez-Du Mortier model to allow frequent calibration, even in near-sea-level site. The Du Mortier are used to determine sky condition over the area of study. From the sky condition models, the calibration constants can be determined by using the improved Langley method. The calibration constants over time then is statistically analysed by using ANOVA.

1. *Sky classification Using Du Mortier Model:*

According to Zain-Ahmad *et al.* [9], this model has been used to predict the sky condition at Shah Alam site located in West Malaysia. According to this model, the Nebulosity Index (NI) as indicators of sky type can be computed by the following equations [5]:

$$NI = \left(1 - I_{ed} / I_{eg}\right) / \left(1 - C_r\right) \tag{1}$$

The theoretical cloud ratio C_r is defined as [5]:

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$$C_r = \frac{I_{Icd}}{\left[I_{Icd} + \exp(-4m' R_s)\sin\beta\right]} \tag{2}$$

Where β is the solar angle, I_{Icd} is the theoretical clear sky diffuse illuminance, m' is the optical mass and R_s is the Rayleigh scattering coefficient [5]. The clear sky illuminance, I_{Icd} can be expressed by the following equation [5]:

$$I_{Icd} = 0.0065 + (0.255 - 0.138 \sin\beta)\sin\beta \tag{3}$$

The β is the solar angle. The optical mass, m' can be obtained using the sun calculator program.

The Rayleigh scattering coefficient R_s is defined as [5]:

$$R_s = 5.4729 + m\{3.0312 + m[-0.6329 + m(0.091 - 0.00152\, m)\}]\}^{-1} \tag{4}$$

The classification of sky conditions by Nebulosity Index is shown in Table 1.

Table 1: Du-Mortier classification of sky conditions [9].

Values of NI	Sky Conditions
0.00 $<$ NI $<$ 0.05	Overcast
0.05 $\leq$ NI $<$ 0.20	Intermediate Overcast
0.20 $\leq$ NI $<$ 0.70	Intermediate Mean
0.70 $\leq$ NI $<$ 0.95	Intermediate Blue
0.95 $\leq$ NI $<$ 1.00	Blue

2. *Langley method:*

The improved Langley method which depends on a known calibration for a reference wavelength to permit calibration at the others by assuming the relative size distribution of aerosol to remain constant as equation (5), so that the ratio of aerosol optical depth between the different wavelengths are assure to be constant as equation (6) [1]:

$$\tau_a(\lambda, t) = \pi A(t) \int K_{ext}(r, \lambda) f(r) d \ln r \tag{5}$$

$$\frac{\tau_a(\lambda_1 t)}{(\lambda_2 t)} = \frac{\tau_a(\lambda_1 t_\circ)}{\tau_a(\lambda_2 t_\circ)} = \psi \tag{6}$$

Where τ_a is the optical depth of aerosol, $f(r)$ is the relative size distribution that is dependent only on particle radius r , and $A(t)$ is the multiplier necessary to produce the correct size distribution at some time r [1].Thus the calibrations at the other wavelengths can be performed by using the reference wavelength as equation (7) [1]:

$$\ln F(\lambda_1) + m(\tau_m(\lambda_1) + \tau_o(\lambda_1)) = \ln F_o(\lambda_1) - \psi m \tau_a(\lambda_o) \tag{7}$$

Where λ_o, λ_1 are the reference wavelength and the calibrated wavelength, respectively, m is the approximate air mass and ψ is a constant. Because $m\tau_a(\lambda_o)$ has been calibrated well, it is calculated accurately $\ln F_o(\lambda_1)$ by least square regression for equation (7) between the left item and $m\tau_a(\lambda_o)$ [1]. It is possible to improve calibration accuracies by selecting the long wavelength with being calibrated well by improved Langley method as reference to perform calibration at the others [1].

Experimental Methodology:

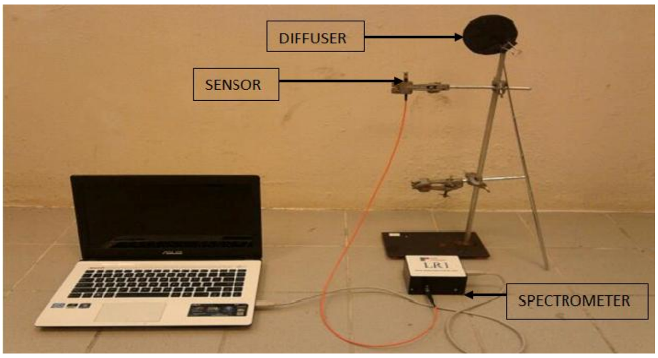

Fig. 1: Spectrometer set up.

Numerous data was collected using a spectrometer according to Figure 1. All the data was filtered according to the Du-Mortier model for determining the sky conditions in Kota Kinabalu and identify the highest nebulosity index to determine the calibration constants using the common Langley method and improved Langley method.

There were 3 locations of studies that were conducted in Kota Kinabalu. The main location of study was conducted in School of Science and Technology inside the Universiti Malaysia Sabah (UMS) compound (6° 2’ N, 116° 7’ E) followed by Damai (5° 58’ N, 116° 5’ E) and Queen Elizabeth Hospital (5° 55’ N, 116° 2’ E) Kota Kinabalu. The location of study was of great importance due to the coordinates of each location that was used in the calculation of the nebulosity index.

A higher ground level was chosen so that the solar pathway was not blocked by irrelevant objects such as artificial buildings or tall trees, thus gave the constant availability of sunlight. First, the spectrometer collected the intensity of sunlight. Solar intensities data collections were collected every minute interval hourly from 8.30am to 4.30pm. The data collected was for the month of July and August of 2012, as well as month of January, February, March and April of 2013. Every data collected in every minute interval was collected twice. First as “Global”, which means direct radiation from the sun, and “Diffused”, which means diffused radiation from the sun. Diffused radiation data was collected using a diffuser.

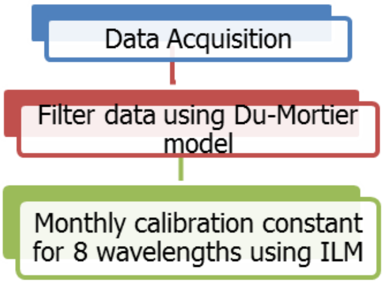

Fig. 2: Schematic diagram for obtaining the monthly calibration constants.

The monthly calibration constant for 8 wavelengths using the improved Langley method was calculated using the formulas from (5), (6) and (7). The improved Langley method used for determining the calibration constant was compared for both the highest sky classifications of the Du-Mortier model. Then the calibration constants are compared using ANOVA.

RESULT AND DISCUSSION

1. *Descriptive Statistic Analysis:*

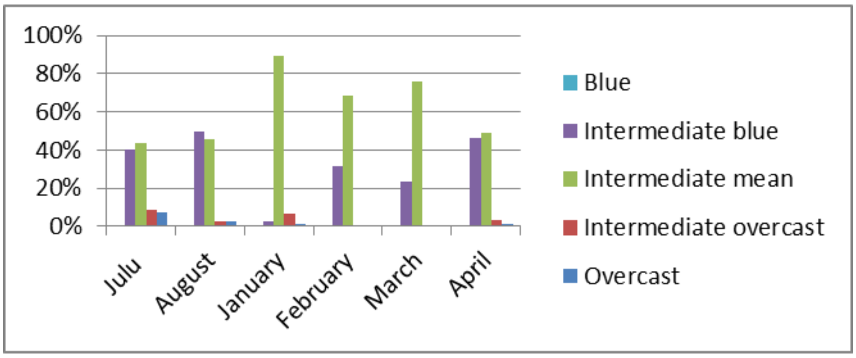

Fig. 3: Nebulosity indices (NI) classifications using the Du Mortier model.

According to Figure 3, all the months that were taken into consideration mostly had sky condition of intermediate mean which is between the range of $0.20 \leq NI < 0.70$ as the majority occurrences of sky conditions in Kota Kinabalu. However, for the month of August alone, the majority of sky condition was intermediate blue which lies between the ranges of $0.70 \leq NI < 0.95$ with a frequency occurrence of 49.47%.

Therefore, based on Figure 3, a decision was made where the data that consists of the highest nebulosity index respectively is taken into consideration for developing the calibration constant to obtain the most accurate result.

2. Statistical Analysis – Calibration Factor with Improved LM:
Nebulosity Index:

An one-way 6 x 8 Randomized Block Design analysis with $n = 1$ per cell was performed on the calibration factor based on Clearness Index data. The null hypothesis was that mean calibration constants were equal across months. The statistical alternative hypothesis was that mean calibration constant was unequal across months.

Table 2: Effect of Times on Calibration Constant of Du Mortier Model, where Wavelengths are Blocks.

Source of Variation	Sum of Squares	df	Mean Square	F	*p*
Month	.019	5	.004	4.838	< 0.05
Wavelength (Block)	2.512	7	.359	458.067	
Error	.027	35	.001		
Total	2.559	47			

Based on ANOVA result in Table 2, the finding showed statistically significant mean difference in calibration index across months ($F = 4.838$, $p = 0.002 < 0.05$). From this result, we know that there are significant differences between the months as a whole.

A Tukey post-hoc test revealed statistically significant differences between mean calibration constants in January and August ($p = .045$), January and March ($p = .030$), January and April (p=0.002), February and April (p=0.030).

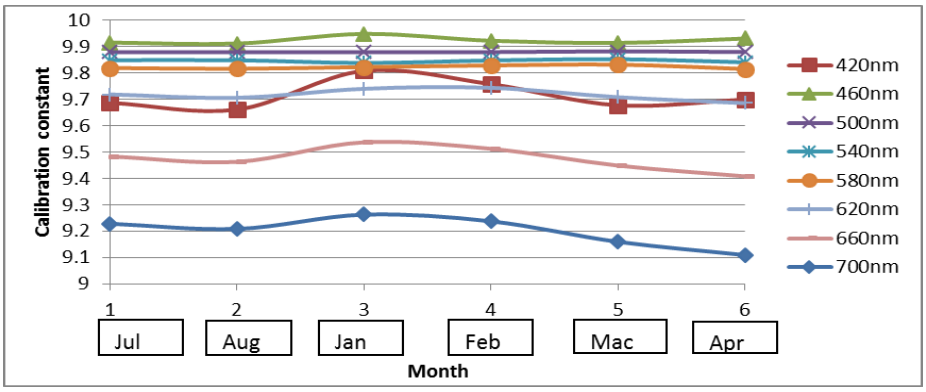

Fig. 4: Variations in calibration constant using Improved Langley method with highest clearness index sky condition.

Scatter plot in Figure 4 showed that majority of the differences are contributed by variation in calibration constant of wavelength 420nm, 660nm and 700nm. Hence, by taking out these wavelengths, we performed a One Way 6 x 5 Randomized Block Design with N = 1 per cell on the remaining data (Wavelength = 460nm, 500nm, 540nm, 580nm and 620nm).

Table 3: Effect of Times on Calibration Constant of Du Mortier Model, where Wavelengths are Blocks (Wavelength = 460nm, 500nm, 540nm, 580nm and 620nm).

Source of Variation	Sum of Squares	df	Mean Square	F	*P*
Month	.001	5	.000	1.381	.273
Wavelength (Block)	.144	4	.036	255.280	< 0.05
Error	.003	20	.000		
Total	.148	29			

Based on ANOVA result in Table 3, the findings showed no statistically significant mean difference in calibration constants across all the months studied ($F = 1.381$, $p = 0.273 > 0.05$).

From the statistical analysis obtained, we know that there are significant differences between the months as a whole. The Tukey post-hoc test determined the specific months that differed. From the Du Mortier model, this model agreed that there were statistically significant differences between mean calibration constants for January and August, January and April as well as February and April.

From the results obtained, calibration constant are considered equal across months for wavelength = 460nm, 500nm, 540nm, 580nm and 620nm. The reason why wavelengths of 460nm, 540nm, 580nm, and 620nm are consistent for both the Du Mortier model is because these wavelengths are close to the 500nm wavelength which is the most stable wavelength in the visible range. This wavelength has a very high sensitivity toward solar radiation thus resulting in a consistent calibration constant throughout all the months studied. However, in addition to the smaller accuracy of the spectrometer measurements, decreasing sensitivity of the spectrometer at 660nm and 700nm and weaker irradiance of the sun at 420nm contribute to the greater deviations in these wavelengths [8].

Conclusion:

In a nutshell, overall the Du Mortier model agreed those months has significant effect on the calibration factors. The differences are specifically happens between January and August, August and February, January and March, January and April as well as February and April. This indicates that there are significant differences between the months as a whole. However, when wavelengths of 420nm, 660nm and 700nm were excluded from the statistical analysis, findings showed no statistically significant mean difference in calibration constants across the months studied for Du Mortier ($F = 2.275$, $p = 0.086 > 0.05$) model. Thus, when only wavelengths of 460nm, 500nm, 540nm, 580nm and 620nm are taken into account, the variations over time of the Perez and Du Mortier calibration constants are consistent. Therefore, calibration constants obtained from Du Mortier calibration algorithm is valid over time.

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REFERENCES

[1] Arai, K., X.M. Liang, 2011. Comparative Calibration Method between Two Different Wavelengths with Aureole Observations at Relatively Long Wavelength. International Journal of Applied Science, 2: 93-101.

[2] Azhari, A.W., M.A. Alghoul, S.H. Zaidi, A.H. Ibrahim, J.M. Abdul Ateef, A. Zaharim, K. Sopian, 2012. Development of Diffused Solar Radiation Maps using GIS Software for Malaysia. Models and Methods in Applied Sciences, 124-128.

[3] Muzathik, A.M., W.M.N. Wan Nik, K. Samo, M.Z. Ibrahim, 2010. Hourly global solar radiation estimates on a horizontal plane. Journal Physical Science, 21(2): 51-66.

[4] Borhanazad, H., S. Mekhilef, R. Saidur, G. Boroumandjazi, 2013. Potential Application of Renewable Energy for Rural Electrification in Malaysia. Renewable Energy, 59: 210-219.

[5] Djamila, H., C.C. Ming, S. Kumaresan, 2010. Estimation of The Exterior Vertical Daylight For The Humid Tropic of Kota Kinabalu City in East Malaysia. Renewable Energy, 36: 9-15.

[6] Johari, A., S.H. Samseh, M. Ramli, H. Hashim, 2012. Potential use of solar photovoltaic in peninsular Malaysia. International Journal of Renewable Energy Resources, 2: 1-5.

[7] Martunus, Zakaria, R., W.J.N. Fernando, M.R. Othman, 2008. Co2 emission and carbon capture for coal fired power plants in Malaysia and Indonesia. International Conference on Environment (ICENV 2008).

[8] Weihs, P., I. Dirmhirn, I.M. Czerwenka-Wenkstetten, 1995. Calibration of Sunphotometer for Measurements of Turbidity. Theoretical & Applied Climatalogy, 51: 97-104.

[9] Zain-Ahmad, A., K. Sopian, Z. Zainol Abidin, M.Y.H. Othman, 2002. The Availability of Daylight from Tropical Skies: A Case Study of Malaysia. Renewable Energy, 25: 21-30.

[10] Chang, J.H.W., J. Dayou, J. Sentian, 2014. Development of near-sea-level calibration algorithm for aerosol optical depth measurement using ground-based spectrometer. Aerosol and Air Quality Research, 14(1): 386-395.