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MODELLING OF SUNSHINE DURATION FOR PENINSULAR MALAYSIA

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MODELLING OF SUNSHINE DURATION FOR PENINSULAR MALAYSIA

By

WIN MAW HLAING OO

Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Science and Environmental Studies
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LIST OF SYMBOLS AND ABBREVIATIONS

Symbols

a and *b*	Parameters of Angstrom type equation (Equation 2.2) Parameters of beta distribution function (Equation 3.40)
C and γ	Parameters of probability distribution functions of relative sunshine duration
D	Maximum difference between empirical and theoretical cumulative distribution curves
$D_{0.01}$	Critical value of K-S test at 1% significant level
$D_{0.05}$	Critical value of K-S test at 5% significant level
$F(x)$	Cumulative distribution function of variable *x*
G_{sc}	Solar constant (1367 Wm^{-2})
H	Daily global solar radiation (MJm^{-2} or KWh)
$\overline{H}$	Monthly mean daily global solar radiation
H_0	Daily extraterrestrial solar radiation
$\overline{H}_0$	Monthly mean daily extraterrestrial solar radiation
K	Daily clearness index (ratio of daily global solar radiation to extraterrestrial solar radiation)
K_{max}	Maximum value of clearness index
K_{min}	Minimum value of clearness index
$\overline{K}$	Monthly mean daily clearness index
N	Number of data points
n	Day of the year (*n* = 1,2 … 365, or 366)

$P(x)$	Probability density function of variable x
Q	Values of Box-Pierce and Ljung-Box statistics
r	Correlation coefficient
S	Daily actual sunshine duration (hr)
$\overline{S}$	Monthly mean daily actual sunshine duration
S_0	Daily maximum sunshine duration (hr)
$\overline{S}_0$	Monthly mean daily maximum possible sunshine duration
s	Daily relative sunshine duration (ratio of daily actual sunshine duration to maximum possible sunshine duration)
$\overline{s}$	Monthly mean daily relative sunshine duration
t	Index of daily time step (used in chapter 4)
x	Normal distributed variable with zero mean and unit variance (used in chapter 4)
δ	Solar declination (degree or radian)
ε	Uncorrelated random variables with normal distributions
ϕ	Latitude of the location (degree)
$\phi_{k,k}$	Partial autocorrelation coefficient at lag k
$\phi_1, \phi_2, \ldots, \phi_p$	Parameters of autoregressive p^{th} order process
ρ_k	Autocorrelation coefficient at lag k
σ	Standard deviation
σ^2	Variance
ω	Sunset hour angle (degree or radian)

Abbreviations

ACF	Autocorrelation function
AR(p)	Autoregressive p^{th} order process
CDF	Cumulative Distribution Function
K-S test	Kolmogorov-Smirnov test
PACF	Partial autocorrelation function
PDF	Probability Density Function
χ^2 test	Chi-square test

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MODELLING OF SUNSHINE DURATION FOR PENINSULAR MALAYSIA

By

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December 1997

Chairman: Professor Mohd. Yusof Sulaiman, Ph.D.
Faculty: Science and Environmental Studies

Knowledge of solar radiation at any area is important for designing solar energy conversion systems, and is also useful for ecophysiological studies. In the present study, we have analysed the daily sunshine duration records for Peninsular Malaysia and apply them in solar radiation modelling.

Firstly, we fitted Angstrom type equation to solar radiation and sunshine duration, to determine the relation between them. We have found that the seasonal variations of the regression parameters, are different for even two nearby locations. Variation of solar radiation within a small area are also noticable.

Secondly, we have studied on the probability distribution nature of daily relative sunshine duration. Daily relative sunshine duration data are fitted to three models. Parameters of the models are estimated only from the monthly mean. Kolmogorov-Smirnov test is applied to determine the goodness of fit. We have found that the four stations can modelled by two distributions. Data are also fitted to well known beta distribution model. The effect of variance is also presented.

Finally, time series analysis of daily relative sunshine duration data are presented in chapter 4. Using gaussian mapping technique, non-stationary and non-normal distribution nature of the sunshine can be transformed into stationary and normal distribution. The autocorrelation function and partial autocorrelation function show the characteristics of autoregressive process. Results from the Box-Pierce and Ljung-Box statistics indicate that the first order autoregressive model is not suitable, while the second order autoregressive model gives satisfactory results. The relative sunshine duration of any day is dependent on the previous two days.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

PEMODELAN TEMPOH SINARAN SURIA UNTUK SEMENANJUNG MALAYSIA

Oleh

WIN MAW HLAING OO

Disember 1997

Pengerusi: **Profesor Mohd. Yusof Sulaiman, Ph.D.**

Fakulti: **Sains dan Pengajian Alam Sekitar**

Pengetahuan mengenai sinaran suria bagi sesuatu kawasan adalah penting di dalam usaha merekabentuk sistem penukaran tenaga suria serta juga berguna untuk kajian ekofisiologi. Dalam penyelidikan yang dijalankan, rekod tempoh sinaran suria harian bagi beberapa lokasi di Semenanjung Malaysia dianalisa dan kemudiannya digunakan dalam pemodelan sinaran suria.

Pada mulanya, bacaan sinaran suria dan tempoh sinaran telah dipadankan dengan persamaan jenis Angstrom bagi memastikan hubungan antara kuantiti tersebut. Didapati bahawa perubahan disebabkan oleh musim ke atas parameter regresi adalah ketara walaupun untuk dua

kawasan yang berhampiran. Perubahan sinaran suria dalam satu kawasan yang kecil juga dapat dilihat dengan jelas.

Kedua, kami juga telah menjalankan kajian ke atas sifat taburan kebarangkalian tempoh sinaran relatif harian dan ianya telah dipadankan kepada tiga jenis model. Parameter-parameter model dianggarkan hanya dari min bulanan bacaan sinaran suria sahaja. Ujian Kolmogorov-Smirnov dijalankan bagi menentukan kesesuian hasil pemadanan dan didapati empat stesyen boleh dimodelkan oleh dua taburan. Data juga telah dipadankan kepada model taburan Beta yang lebih terkenal.

Akhirnya, analisis menggunakan siri masa ke atas tempoh sinaran relatif harian diberikan di dalam bab 4. Dengan menggunakan teknik pemetaan Gaussian, jenis taburan tidak pegun dan tak normal sinaran suria telah ditransformasikan kepada taburan berbentuk pegun dan taburan normal. Fungsi otokorelasi biasa dan otokorelasi separa dapat menunjukkan sifat proces otoregresif. Hasil yang diperolehi dari statistik Box-Pierce dan Ljung-Box menunjukkan bahawa model otoregresif jenis pertama tidak sesuai digunakan sementara model otoregresif jenis kedua menghasilkan keputusan yang memuaskan. Tempoh sinaran suria dua pada sebarang hari adalah bergantung kepada tempoh sinaran suria pada dua hari sebelumnya.

CHAPTER 1

INTRODUCTION

Measurement of solar radiation is important in developing solar energy devices to supplement existing energy sources. This is of particular importance for country like Malaysia where the solar radiation is available in abundance throughout of the year. There are also other uses of such information in quantitative ecophysiological studies such as the source of energy used in photosynthesis and evapotranspiration.

The solar radiation climatology of the world has been extensively studied by numerous researchers in the past. However, since solar radiation reaching the earth's surface depends on the factors such as cloud cover, water vapour contents, and other meteorological factors which are not consistent globally, the measurements of on-site radiation data are essential. But unfortunately, for most of the locations, a detailed historical record (without missing values) of the solar radiation values does not exist. And even for locations having reliable data, the effort of incorporating them in applications require the user to handle enormous amount of data.

To overcome this problem, a stochastic model, which can explain the statistical properties of historical records, only from summarized parameters (e. g. monthly mean) need to be developed.

In the present study, we analysed the daily sunshine duration data for Peninsular Malaysia to apply in solar radiation modelling. Sunshine duration is one of the meteorological parameter which is most correlated to solar radiation.

Daily sunshine duration is the total time during the day when the sun in unobscured by cloud. And it can be measured easily using simple devices such as Campbell-Stokes sunshine recorder (Linacre, 1992). Sunshine duration measurements are available at many more locations than solar radiation, and it can be used for model construction and calibrations.

Objectives of the Study

The overall purpose of this work is to derive a mathematicai model of daily sunshine duration. The model requires a minimum number of parameters that are readily assessable.

More specifically the objectives are to:

- determine the correlation between solar radiation and sunshine duration. The results can be applied in the estimation of the global solar radiation from sunshine duration.

- study the probability distribution nature of daily relative sunshine duration. The results will determine the appropriate probability density and cumulative distribution function of the relative sunshine duration.

- study for the sequential structure of daily relative sunshine duration. The results will be useful in the construction of a time series model which can generate a long term synthetic sequence of daily sunshine duration.

Brief Descriptions of Climate of Peninsular Malaysia

Peninsular Malaysia is located roughly between 1° and 6° north latitude and 100° and 104° longitude east. The country is bordered by Thailand in the north. The South China sea on the east side of the country, while the strait of Malacca on the west coast separates the peninsula from Sumatra.

The climate of Peninsular Malaysia has seasonal rhythm, mainly determined by changes in directions and speed of the air streams that cross the peninsula (Dale, 1959).

Temperature conditions are best characterized by the term 'uniformity'. This applies to the lack of seasonal variation and the annual range of temperature everywhere in the country remains low. The daily cycle of the temperature proceeds usually vary regularly, without large variations from day to day, such as occur in the temperate climates.

The main characteristic of rainfall in Peninsular Malaysia is its variability. Rainfall is the most changeable element of climate, both in the relation to time and place. Its diurnal, seasonal and annual distributions vary strongly from region to region and from year to year.

The rainy seasons are mainly influenced by the Asian monsoons. The South-west monsoon brings rain and cloud to the west coast from June to early October, while the North-east monsoon brings rain and cloud to east coast from November to March. Therefore, the west coast is dry from November to March while the east coast is dry from June to September.

The relative humidity of the lower atmosphere in Peninsular Malaysia is usually high. Mean values at night-time for all stations are between 95% and 100%, only the day-time values have the regional and seasonal differences.

Locations of the Study and Availability of Data

Daily global solar radiation and sunshine duration for ten years [1985-1994], are supplied by the Meteorological Department, Ministry of Science, Technology and Environment of Malaysia. The data are for four stations, namely, Petaling Jaya, Subang, Bayan Lepas and Kota Bharu. The locations of these stations are described in Table 1 and Figure 1.

Table 1: Locations of the Stations

Stations	Latitude	Longitude	Altitude
Petaling Jaya	3° 06' N	101° 39' E	45.7 m
Subang	3° 07' N	101° 33' E	16.5 m
Bayan Lepas	5° 18' N	100° 16' E	2.8 m
Kota Bharu	6° 10' N	102° 17' E	4.6 m

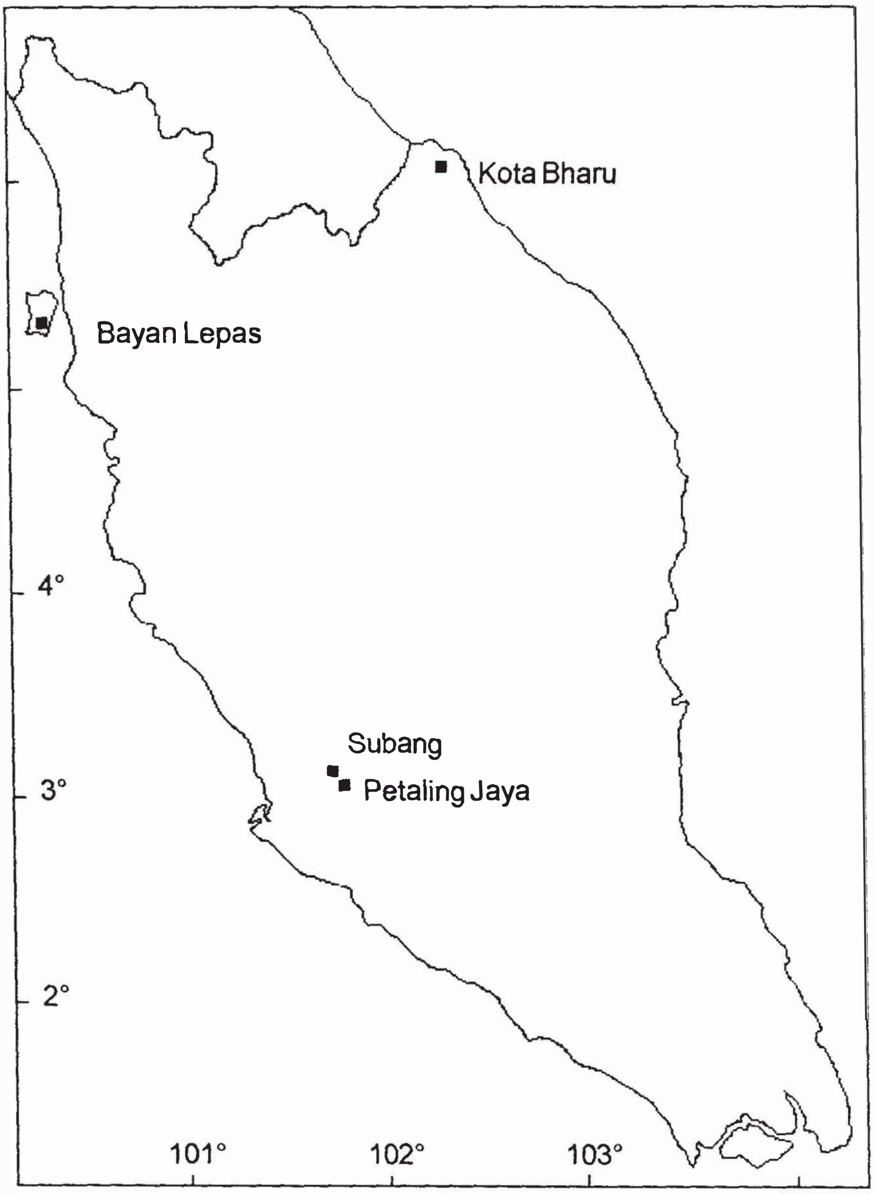

Figure 1: Map of the Locations of the Stations Used in the Study