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The Influence of Atmospheric Aerosol on Solar Radiation Degradation in Each Region of Thailand

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ABSTRACT

The analyses on the influence of atmospheric aerosol using solar radiation and meteorological data, during January-December 2004 from twenty agro-meteorological and meteorological stations were carried out. The investigation was based on the comparison of solar radiation obtained from measurement. It was found that the highest monthly solar radiation due to aerosols in the atmosphere with aerosol on clear sky day amount during April was about 23 %. While the monthly average depletion of solar radiation occurred in the North, Central, North-East and South were about 21.76 %, 20.71 %, 17.16 % and 13.10% respectively. Statistical analysis by F-test comparison on the regional of solar radiation depletion was found that Northern, North-Eastern and Southern were significantly different at 95% confidence level except in the North and Central, which was found to be non-significantly different at 95%.The solar radiation depletion due to aerosols in the atmosphere during summer solstice (April-May) and rainy solstice in Thailand (July-September) indicated that the solar radiation depletion during the summer solstice was about 18 %, which was greater than the one during the rainy solstice which was about 11 % due to the forest fire during summer season.

Key words: aerosol, solar radiation, rainy solstice, summer solstice

INTRODUCTION

Atmospheric aerosols play an important role on environments globally and locally. Amount of aerosols in atmosphere are increasing over many regions of the world i.e. Europe, North America, and the North Atlantic. Those particulate matters were released into global atmosphere approximately 10^7 tones per day by both primary and secondary sources (Williamson, 1973). Aerosols are believed to reduce the amount of short wave solar radiation incidenting on the earth's surface. Aerosols can also absorb and scatter short wave between aerosols and solar short wave affect solar radiation before they reach the earth's surface. The interactions on atmospheric radiative energy transfer and balance. Surface aerosol radiative forcing is defined as the difference between the net flux at the surface and the same quantity when there is no aerosol present in the atmosphere (Brett and Valero, 2003). There are some evidences which reveal that

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atmospheric aerosol can have a significant influence on the radiative balance of the earth (Chylek and Coakley, 1974; Intergovernmental Panel on Climate Change, 2001).

There are many sources of atmospheric aerosols in Thailand such as forest fire, biomass burning, industries effluence, construction and sea salt. The investigations of these aerosols in the tropics especially in Thailand are still very limited and quite less. However, these data which represent the environmental quality in Thailand have rapidly changed due to the manmade aerosols dispersion such as the increasing in fossil fuel and coal uses, and biomass burning.

The objectives of these studies are to analyze solar radiation degradation caused by the aerosol in the atmosphere of each region of Thailand and to compare the solar radiation depletion between summer and rainy solstice.

MATERIALS AND METHODS

1. Both primary and secondary data were collected during Jan-Dec 2004. The primary data were collected from 20 agrometerological stations over Thailand shown in Table 1 while the secondary data were offered by Silpakorn University.

2. Daily data were classified on the basis of cloud covering and change of diurnal solar radiation. Cloud covers are separated by quantity of cloud on clear sky; when the sky has cloud covering less than 1/10, then separation of change of diurnal solar radiation by using graphs of diurnal solar radiation shares normal curve.

3. Analysis of the solar radiation data was carried out by using Nunez (1993) equation:

Table 1 Solar radiation Station in each region of Thailand.

Region	Station	Province
Northern	Mae Jo	Chiang Mai
	Nan	Nan
	Mae Hong Son	Mae Hong Son
	Doi Moo Ser	Tak
	Hang Chat	Lampang
	Chiang Rai	Chiang Rai
North-Easthern	Tha Phra	Khon Khen
	Nong Khai	Nong Khai
	Ubon Ratchathani	Ubonratcha Ratchathani
	Surin	Surin
	Pak Chong	Nakhon Ratchasima
Central	Tag Fa	Nakhon Sawan
	Bang Na	Bangkok
	Kampangesean	Nakhon Pathom
	Lop Buri	Lop Buri
	Kanchanaburi	Kanchanaburi
Sorthern	Surat Thani	Surat Thani
	Narathiwat	Narathiwat
	Phuket	Phuket
	Kho Hong	Songkhla

$$Q_m = Q_o \frac{(1-\delta_a)(1-\phi_o-\phi_w)}{1-\delta_a\delta_g} \quad (1)$$

Where, Q_m is net radiation (MJ/m^2)
Q_o is extraterrestrial radiation (MJ/m^2)
ϕ_w is coefficient of the vapor
ϕ_o is coefficient of the ozone
δ_a is coefficient of the air molecule
δ_g is albedo of surface (%)

The coefficients using were calculated by using equation as followed:

1) Extraterrestrial radiation was calculated by using Iqbal (1983) equation:

$$Q_o = K\left(\frac{d_o}{d}\right)^2 \cos\theta_z \quad (2)$$

where Q_o is extraterrestrial radiation (MJ/m^2)
d_o is average distance from Earth to Sun (km)
d is true distance from Earth to Sun (km)
K is solar constance 4.871 ($MJ/m^2/hr$)

$$\frac{d_o}{d} = 1.0001 + 0.034221 \cos N + 0.00128 \sin N + 0.000719 \cos 2N + 0.000077 \sin 2N$$

$$SD = 0.006918 - 0.39912 \cos N + 0.070257 \sin N - 0.006758 \cos 2N + 0.000907 \sin 2N - 0.0002697 \cos 3N + 0.00148 \sin 3N$$

$$N = \frac{2\times\pi\times n}{365}$$

where n is the value days using in the equation of the year from 0-364 (1st January-31st December)

$\pi = 3.14\ 2$

2) Coefficient of the vapor was calculated as followed:

$$\phi_w = \frac{2.9U_1}{(1+141.5U_1)^{0.635} + 5.929U_1} \quad (3)$$

$U_1 = wm_r$

$m_r = \sec\theta_z$ (degree)

$w = 0.861569\exp(0.1752 rhP_s/T)$

$$P_s = 26.23 - \frac{5416}{T}$$

where ϕ_w is coefficient of the vapor
U_1 is relative optical path length of precipitable water (cm)
m_r is coefficient of the air molecule
w is the vapor (cm)
θ_z is the zenith angle
rh is relativety humidity (%)
T is temperature (K°)
P_s is saturated vapor pressure (mb)

3) Coefficient of the ozone was calculated as followed:

$$\phi_o = \frac{0.02118U_3}{1+0.042U_3+0.000323U_3^2} + \frac{1.082U_3}{(1+138.6U_3)^{0.805}} + \frac{0.0658U_3}{1+(103.6U_3)^3} \quad (4)$$

$U_3 = Im_r$

where ϕ_o is coefficient of the ozone
U_3 is ozone relative optical path length (cm)
I is amount of ozone (cm)
m_r is air mass (degree)

4) Coefficient of the air molecule was calculated as followed:

$$\delta_a = \frac{0.28}{1 + 6.43\cos\theta_z} \quad (5)$$

$$\cos\theta_z = \sin\delta \sin\phi + \cos\delta \cos\phi \cos\omega$$

where δ_a is coefficient of the air molecule

ω is the hour angle, noon zero and morning positive.

ϕ is the geographic latitude, in degrees, North positive.

δ is the declination, the angular position of the sun at solar noon with respect to the plane of the equator, north positive, in degree.

5) Albedo used constant values on land use at station.

4. Analysis of the solar radiation depletion due to aerosols in the atmosphere was calculated by using equation of Sayan (1999):

$$\Delta Q = \frac{Q_e - Q_m}{Q_e} \quad (6)$$

where ΔQ is solar radiation depletion due to aerosols (MJ/m^2)

Q_m is solar radiation by measurement (MJ/m^2)

Q_e is solar radiation by the calculations (MJ/m^2)

5. Analysis of the solar radiation depletion due to aerosols in the atmosphere on summer solstice (April-May) and rainy solstice (July-September) was carried out by measuring the midday light. Since the amount of solar radiations perpendicular to earth's surface on midday vary in different seasons, therefore analyzing of data in summer solstice compared to rainy solstice will yield the solar radiation depletion due to aerosols. Figure 1 shows the 90° day's solar radiation at various stations on the midday.

RESULTS AND DISCUSSION

1) Solar radiation depletion due to aerosols in the atmosphere of each region

From solar radiation data collected by the measurements from 20 climatic stations, the effect of aerosols were calculated. Such data which were collected during May-September cannot be processed due to rainy season. In contrast, from the data which were collected in April showed the highest depletion. Such highest depletion might be affected by forest fire which took place during the time of peak spreading, because forest fire emitted quite large amount of aerosols.

The result of solar radiation depletion due to aerosols in the atmosphere of each region is shown in Table 2. The highest solar radiation depletion is found in the Northern Thailand as 21.76 %. This result is consistent with forest fire frequency which shows that forest fire occurred in this region more than others (Department of National Park Wildlife and Plant Conservation, 2006). In the North-Eastern regime, the average solar radiation depletion is 17.16 % which is relatively low, because the biomass burning is the main source of many aerosols of the North-Eastern regime. In the Central, the average of solar radiation depletion is 20.71%. This high value might be the effects of aerosols which generated from urban activities i.e. anthropogenic biomass burning, industries and construction. The lowest depletion is found in the South with a value of 13.10% sine there are a lot of rain in the Southern almost all the year. The clear sky in this region may be affected from a longer rainy season than in other regions.

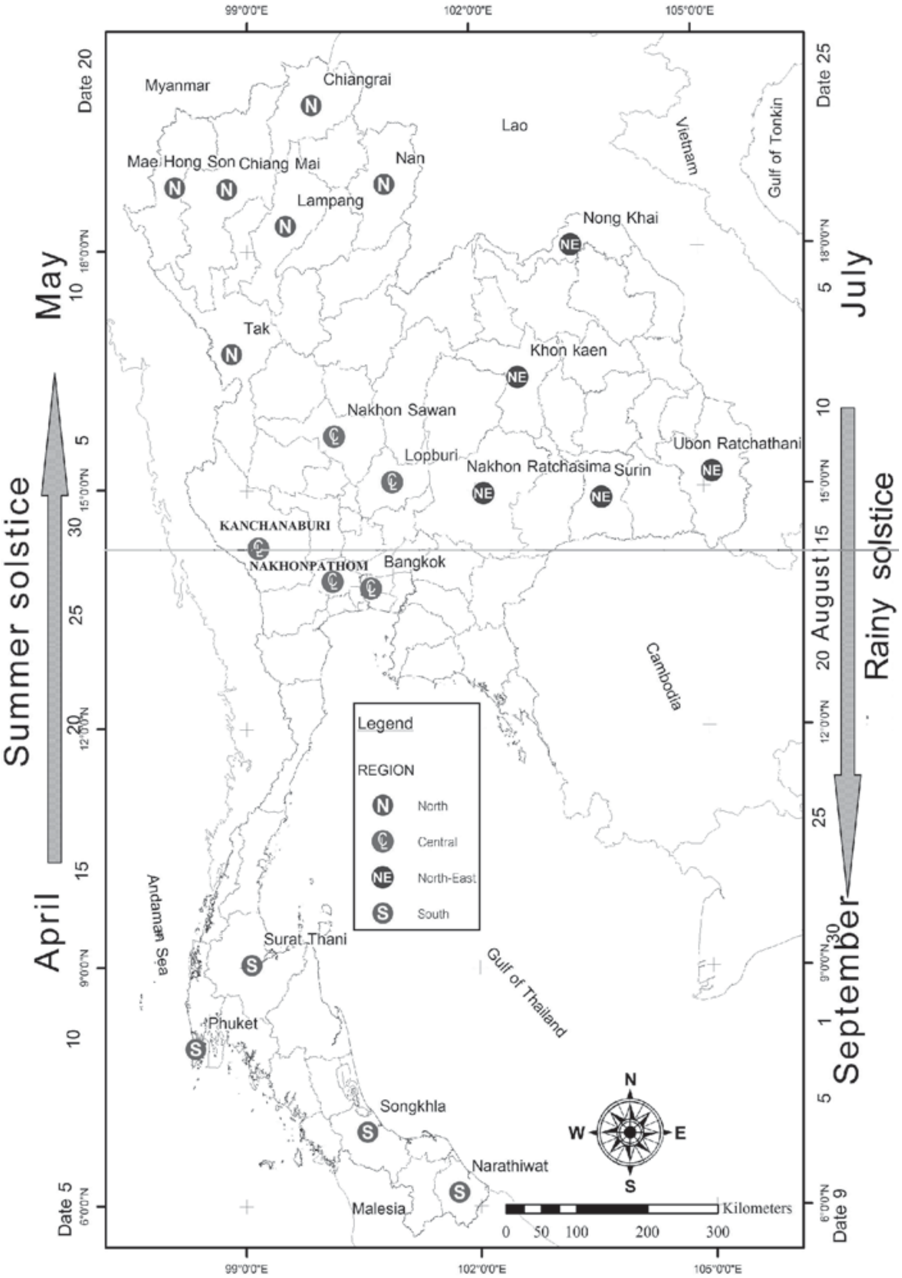

Figure 1 Map of Thailand determining solar radiation depletion in Thailand due to aerosols in the atmosphere on summer solstice and rainy solstice year 2004.

Table 2 Solar radiation depletion (%) due to aerosols in the atmosphere of each region year 2004.

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Northern	21.22	20.28	21.79	30.51	-	-	-	-	-	19.76	19.16	19.61	21.76[a]
North-Eastern	20.28	15.54	16.33	21.37	-	-	-	-	-	16.22	15.62	14.76	17.16[b]
Central	21.30	17.87	22.79	21.39	-	-	-	-	-	19.71	20.65	21.24	20.71[a]
Southern	12.20	10.70	11.61	12.49	-	-	-	-	-	14.83	14.10	15.76	13.10[c]

Note: Mean values in a column followed by letters is shown significantly different at 5% level according to F-test.

2) Solar radiation depletion due to aerosols in the atmosphere in the summer and rainy solstice

Table 3, Table 4 and Figure 2 show solar radiation depletion due to aerosols in the atmosphere in summer solstice and rainy solstice. The results show that solar radiation depletion due to aerosols in the atmosphere on summer solstice is higher than in rainy solstice. Since during April-May is dry season while July-September is rainy season, therefore rain could decrease amount of aerosols in the atmosphere during rainy season then solar radiation reaches the earth's surface is greater than in the dry season. The calculation on summer solstice and rainy solstice for comparing the solar radiation was done on the primary data which collected at midday, because the maximum solar radiation occurred during that time.

CONCLUSION

The influences of atmospheric aerosol on solar radiation degradation in each region of Thailand are increasing. It will be affected to solar radiation on the earth as follows:

The average solar radiation depletion due to aerosols in the atmosphere is highest (23%) in April. Comparison among four regions, solar radiation depletion in the North is the highest (21.76 %), while the Central, the North-East and the South solar radiation depletion are about 20.71 %, 17.16 % and 13.10%, respectively.

As the result, solar radiation depletion due to aerosols in summer solstice was about 18 % while in rainy solstice was about 11 %, because of the forest fire which occurred during summer. In addition, rainfall during rainy season decreased the amount of aerosols in the atmosphere. Therefore, solar radiation depletion in rainy solstice was less than summer solstice.

The results of this study can be applied for environmental planning and management of which is affect of air pollution and can be analyzed the weather for visibility to fly.

However, classification of aerosols in the study is not conducted, so the further in the study should be undertaken for validity of the results.

Table 3 Solar radiation depletion due to aerosols in the atmosphere on summer solstice(April-May) year 2004.

Station	D/M/Y	Solar radiation depletion due to aerosols in the atmosphere hourly (%)													Mean
		6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	
Chiang Rai	26/5/2547	-	-	-	-	16	25	-	-	-	-	-	-	-	21
Mean		-	-	-	-	16	25	-	-	-	-	-	-	-	21
Mae Hong Son	16/5/2547	-	-	-	25	15	11	10	7	-	-	-	-	-	14
Mae Hong Son	17/5/2547	-	-	-	-	-	-	-	-	7	15	-	-	-	11
Mae Hong Son	24/5/2547	-	-	-	-	-	10	-	-	-	-	-	-	-	10
Mae Hong Son	25/5/2547	-	-	-	-	-	19	-	-	-	-	19	-	-	19
Mean					25	15	13	10	7	7	15	19	-	-	13
Chiang Mai	13/5/2547	-	-	-	9	-	-	-	-	-	-	-	-	-	9
Chiang Mai	15/5/2547	-	-	-	-	20	-	-	-	-	-	-	-	-	20
Chiang Mai	16/5/2547	-	-	-	-	-	16	-	-	-	-	-	-	-	16
Chiang Mai	17/5/2547	-	-	-	14	9	-	-	-	-	-	-	-	-	12
Mean					12	15	16	-	-	-	-	-	-	-	14
Nan	9/5/2547	-	-	-	-	-	-	19	-	-	-	-	17	-	18
Nan	10/5/2547	-	-	-	23	-	-	-	-	-	-	-	-	3	13
Nan	13/5/2547	-	-	-	24	-	-	-	-	-	-	-	-	-	24
Mean		-	-	-	24	-	-	19	-	-	-	-	17	3	18
Surin	27/4/2547	-	-	21	-	-	-	-	-	-	-	-	-	-	21
Surin	28/4/2547	-	-	-	-	-	-	-	29	24	-	-	-	-	26
Surin	29/4/2547	-	-	23	-	-	-	-	-	-	-	-	-	-	23
Mean		-	-	22	-	-	-	-	29	24	-	-	-	-	23
Nakhon Ratchasima	30/4/2547	-	31	-	-	-	-	-	-	-	-	-	-	-	31
Mean		-	31	-	-	-	-	-	-	-	-	-	-	-	31
Lopburi	24/4/2547	-	-	-	-	-	-	-	-	-	-	-	-	30	30
Lopburi	25/4/2547	-	-	-	-	-	-	-	-	-	-	-	7	-	7
Lopburi	26/4/2547	-	-	-	-	-	-	-	-	-	-	29	-	-	29
Lopburi	29/4/2547	-	-	-	-	-	-	-	-	-	-	29	-	-	29
Mean		-	-	-	-	-	-	-	-	-	-	29	7	30	24
Bangkok	24/4/2547	-	-	-	-	-	-	-	-	-	-	-	16	-	16
Bangkok	25/4/2547	-	-	-	13	14	-	-	-	-	-	-	-	-	14
Bangkok	26/4/2547	-	-	-	-	26	-	-	19	15	24	-	-	-	21
Mean		-	-	-	13	20	-	-	19	15	24	-	16	-	17
Phuket	9/4/2547	-	-	-	-	-	20	13	19	26	24	-	-	-	20
Phuket	11/4/2547	-	-	-	-	-	-	10	-	23	21	-	-	-	18
Phuket	12/4/2547	-	-	-	-	-	-	-	-	-	-	7	-	-	7
Mean		-	-	-	-	-	20	11	19	25	22	7	-	-	15
Narathiwat	2/4/2547	-	-	-	11	18	14	-	-	-	-	-	-	-	14
Narathiwat	6/4/2547	-	-	-	14	12	11	19	-	-	-	-	-	-	14
Mean		-	-	-	13	15	13	19	-	-	-	-	-	-	14
Total Average		-	-	-	17	16	16	14	19	18	21	20	13	16	**18**

Note:(-) The time were cloudy sky

Table 4 Solar radiation depletion due to aerosols in the atmosphere on rainy solstice (July-September) year 2004.

Station	D/M/Y	Solar radiation depletion due to aerosols in the atmosphere hourly (%)													Mean
		6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	
Chiang Rai	25/7/2547	-	-	-	-	13	-	-	-	-	-	-	-	-	13
Chiang Rai	26/7/2547	-	-	-	19	1	-	-	-	-	-	-	-	-	10
Chiang Rai	28/7/2547	-	-	-	-	-	-	-	-	-	-	-	-	13	13
Mean					19	7	-	-	-	-	-	-	-	13	12
Mae Hong Son	25/7/2547	-	-	-	-	-	-	-	-	-	17	-	-	-	17
Mae Hong Son	26/7/2547	-	-	-	-	-	-	-	-	-	-	9	-	13	11
Mae Hong Son	27/7/2547	-	-	-	-	-	-	-	-	13	1	6	-	-	7
Mean		-	-	-	-	-	-	-	-	13	9	8	-	13	12
Nan	28/7/2547	-	-	-	-	-	-	-	15	-	-	-	-	-	15
Nan	3/8/2547	-	-	-	-	-	-	-	-	-	-	-	12	-	12
Mean		-	-	-	-	-	-	-	15	-	-	-	12	-	13
Surin	12/8/2547	-	-	9	-	-	-	-	-	-	-	-	-	-	9
Surin	14/8/2547	-	-	-	-	-	-	-	-	-	12	-	-	-	12
Surin	15/8/2547	-	-	-	14	-	-	-	-	-	-	-	-	-	14
Surin	16/8/2547	-	-	11	-	-	-	-	-	-	-	18	-	-	15
Surin	17/8/2547	-	-	3	-	-	-	-	-	-	-	-	-	-	3
Mean		-	-	8	14	-	-	-	-	-	12	18	-	-	11
Nakhon Ratchasima	12/8/2547	-	-	12	-	-	-	-	-	-	-	-	-	-	12
Nakhon Ratchasima	18/8/2547	-	-	-	-	-	-	-	-	-	-	-	10	-	10
Mean		-	-	9	14	-	-	-	-	-	12	18	10	-	11
Bangkok	11/8/2547	-	-	-	-	-	-	-	-	11	15	-	-	-	13
Bangkok	12/8/2547	-	-	-	-	17	-	-	12	-	-	-	-	-	14
Bangkok	18/8/2547	-	-	-	3	13	13	8	30	15	-	-	-	-	14
Bangkok	19/8/2547	-	-	-	-	21	-	-	-	-	-	-	-	-	21
Mean		-	-	-	3	17	13	8	21	13	15	-	-	-	15
Phuket	30/8/2547	-	-	-	-	-	-	-	-	-	-	-	6	-	6
Phuket	1/9/2547	-	-	-	-	-	10	-	-	15	7	9	-	-	10
Phuket	3/9/2547	-	-	-	-	-	-	-	13	-	-	-	-	-	13
Phuket	6/9/2547	-	-	-	1	-	-	-	-	-	-	-	-	-	1
Mean		-	-	-	1	-	10	-	13	15	7	9	6	-	8
Narathiwat	31/8/2547	-	-	13	-	-	-	-	-	-	-	-	-	-	13
Narathiwat	2/9/2547	-	17	-	-	-	-	-	-	-	-	11	-	-	14
Narathiwat	4/9/2547	-	-	-	-	-	-	-	-	2	7	11	-	-	7
Narathiwat	5/9/2547	-	-	-	-	-	-	-	-	5	-	-	-	-	5
Narathiwat	6/9/2547	-	-	-	-	5	10	13	5	-	14	-	-	-	9
Narathiwat	7/9/2547	-	-	7	-	-	-	-	-	20	-	-	-	-	13
Mean		-	17	10	-	5	10	13	5	9	11	11	-	-	10
Total Average		-	17	9	9	12	11	10	15	12	11	12	9	13	**11**

Note:(-) The time were cloudy sky

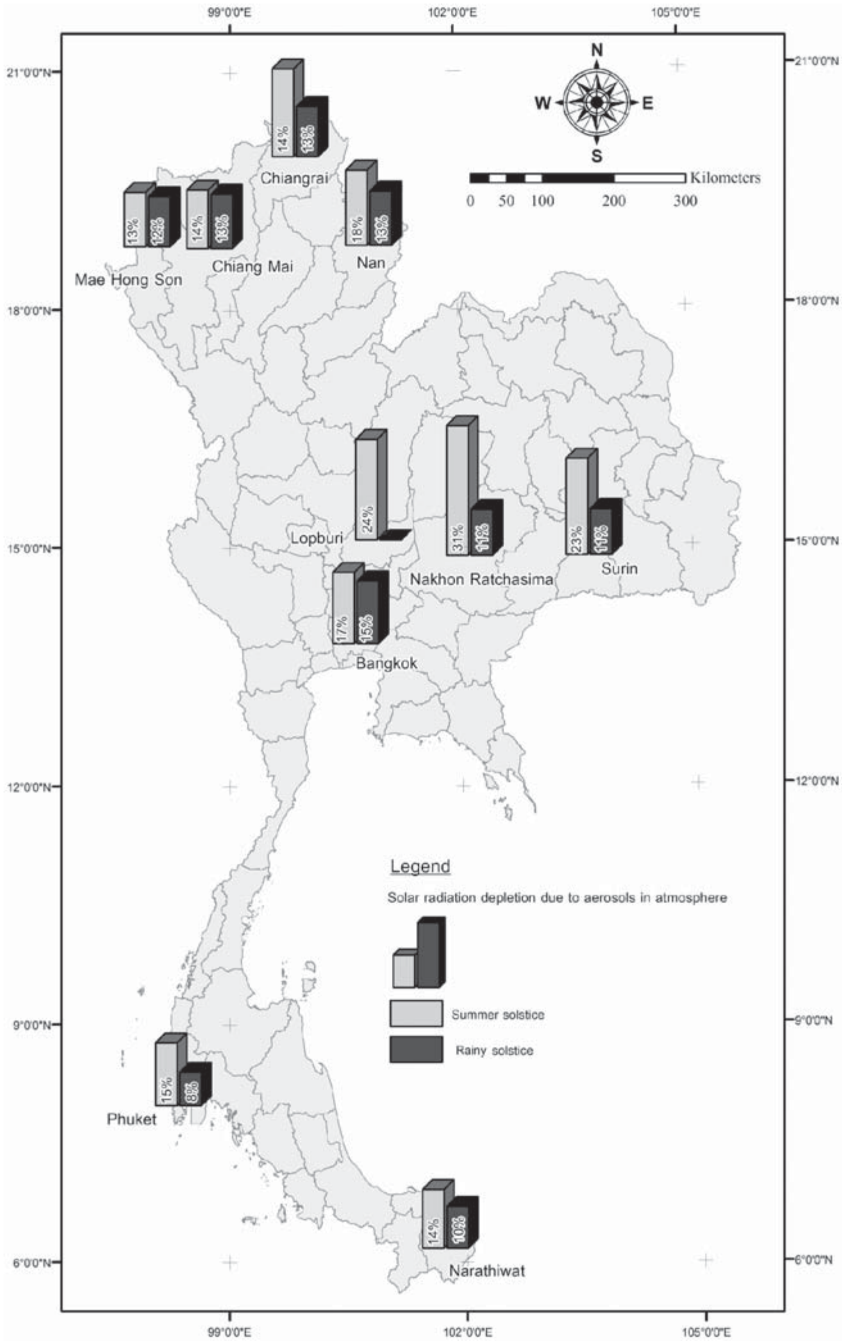

Figure 2 The mid-day Solar radiation depletion due to aerosols in the atmosphere on summer solstice (April-May) and rainy solstice (July-September) year 2004.

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