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Global Dimming Situation in the Central Region of Thailand

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Abstract

A declined trend of surface solar radiation (SSR), the so call Global Warming, has as wide impact to human as global warming. However, there are lacked of empirical evidences about global dimming in the region of Southeast Asia. This study aims to establish knowledge and to understand patterns of global dimming in the central region of Thailand. The method of research began with data collection, which is composed of statistic data acquired from climatological measured stations. The trend of yearly average surface solar radiation was monitored in two periods; before and after 1990 periods. The results showed that the average annual solar radiation intensity trend in Central of Thailand, during the year before 1990 from the average daily radiation estimation model have not change significantly, except rainy season. However, the annual average solar radiation intensity during the later year 1990 showed a significant decrease in the level of 0.05. The tendency of solar radiation intensity has highly changed in the winter. This result was indicated that the central region of Thailand has been entering into the period of global dimming. In order to cope with this situation, it needs policy recommendation in terms of land use control, green area increasing, and transportation management.

Index Terms— Global Dimming, Surface Solar Radiation, Central of Thailand.

I. Introduction

Global dimming is a phenomenon in which the intensity of the solar radiation is reduced to the surface of the earth. The effect of global dimming is estimated to be comparable to the effect of squared global warming [1]. Global dimming causes the Asian monsoon, which is the source of rainfall, to reduce as much as 50 percent of the world's rainfall, thereby causing drought conditions in some areas and ultimately leading to global food shortages. The main cause of global dimming is the change in aerosol. The property of the aerosol is that the nuclei cause the condensation of water vapor in the air to form a cloud that is visible to the eye and then change the state and time of the cloud's appearance in the atmosphere. Aerosols can also absorb heat pollution and remain relatively stable in the air, thereby inhibiting cloud formation, known as the Semi-direct Effect. This result in a reduction in solar radiation due to an increase in aerosol levels in the atmosphere. Natural effects on the thickness of the visible aerosol layers have been found to be negligible except in the case of large volcanic eruptions such as the 1982 El Chichon eruption and the 1991 Pinatubo. Another problem is caused by human activities: 1) the increase in industry and aerosols as a result of urban production. 2) The change in intensity of solar radiation that hits the Earth's surface varies with the latitude relative to the pollution source. The intensity of solar radiation that hit the Earth's surface was proven and compared with estimates of fossil fuel emissions) in the 1960s and 1990s. Latitude represents a decrease in the intensity of solar radiation that hit the Earth's surface and an increase in fuel emissions is estimated at 35 degrees north latitude. This corresponds to a region with high industrial activity and a very dense population[2] In addition, several studies have shown the effects of aerosols caused by human activities to cause a decrease in the intensity of the solar radiation that hit the Earth's surface at 58W/m^2. The dataset was used in 1958-1985 and was highly correlated with the increase in the number of vehicles on the highway [3]. Moreover, further studies have found apparent global dimming in densely populated urban areas. Therefore, it can be concluded that in general, aerosols produced by human activities play a significant role in the change in the thickness of the visible aerosol layer and in relation to the change in the intensity of solar radiation hitting the Earth's surface [4] [5].

Scientists became interested in global dimming from 1950-1980. They found that in Europe and the Americas, the intensity of solar radiation hitting the Earth's surface tends to decrease steadily [6]. Since this was the time when the industrialization of the continent took place, a large amount

of aerosols was produced in the atmosphere. However, after 1990, the situation turned out to be the opposite, known as the "Brightening Period". This was due to the movement of industrial production bases to Asia [7]. The global dimming events in Asia had been reported before the 1960s and that large-scale countries such as Russia, China and India had been discovered. Since these countries were the world's most populous countries and were manufacturing bases in various industrial sectors, global dimming was high. In addition, space-limited countries such as Japan and the Hong Kong Special Administrative Region, which had the highest population density rates in the world, had resulted in higher rates of global dimming during this period. Quantitative results for the phenomenon of individual Asian countries [8] showed that during 1958–1992 Russia had a global dimming rate of -1 W/m^2 to -8 W/m^2, and the occurrence of a relative trend for the period decreased by -1% to -7%. [9] was found that during 1961–1989 China had a global dimming rate of -7W/m^2, and the occurrence of a relative trend for the period decreased by -4.6%. [10] was found that during 1971 – 1989 Japan had a global dimming rate of -1.3 W/m^2, and the occurrence of a relative trend for the period decreased by -0.8%. As indicated on the map, Japan's global dimming rate was the lowest of Asia. [11] was found that during 1958–1992 the Hong Kong Special Administrative Region had a global dimming rate of -18 W/m^2, and the occurrence of a relative trend for the period decreased by -10.6%. As indicated in the map, the global dimming rate in the Hong Kong SAR has the highest rate in Asia, and [12] during 1966–1990 India found a global dimming rate of -2.9 W/m^2, and the occurrence of a relative trend for the period decreased by -1.4%. According to various reports, in Southeast Asia, including Thailand, no data on global dimming had been reported.

II. Research Objectives

This study aimed to build a body of knowledge and understanding of global dimming patterns occurring in Thailand. A study was conducted by considering changes in the intensity of solar radiation that hit the Earth's surface in the central region of the country, leading to a solution to mitigate and prevent the effects of global dimming.

III. Research Methods

The widespread interest and study of global dimming began in 1950. It was found that in 1950-1980 the intensity of solar radiation that hit the Earth's surface tended to decrease and the situation had the opposite effect after 1990. We therefore used time points since 1990 to study changes in solar radiation intensity. The information necessary to study the intensity of solar radiation that hits the Earth's surface was the intensity of the solar radiation that hit the Earth's surface. Data could be collected from air quality monitoring stations. However, from the collection of such data, it was found that Thailand was still very limited because no data was collected directly to study the phenomenon before 1990. Therefore, this research applied other side-by-side data to analyze trends in the intensity of solar radiation hitting the Earth's surface. A model was used to estimate the total daily radiation from the difference between the daily maximum and minimum climate temperatures as in equations 1 and 2[13]. The model was developed to fit the Thai case for estimating total daily radiation doses at average monthly rates. It could be measured from the difference between the average daily maximum and minimum ambient air temperature per month [14]. An examination of trends of changes in the intensity of solar radiation that hit the earth's surface during the period after 1990 (1999-2017), data on the intensity of solar radiation that hit the earth's surface could be used from air quality monitoring stations recorded by air quality monitoring stations of relevant agencies, recorded on an hourly and monthly basis (AERONET, NASA, Meteorological Department, Pollution Control Department, Department of Alternative Energy Development and Efficiency).

$$H = a_4 H_0[1-\exp(-b_4(\Delta T)^{c4})] \quad \text{(Equation 1)}$$

where $$\Delta T = T_{max} - T_{min} \quad \text{(Equation 2)}$$

H is the total daily radiation. (Joules per square meter per day)

H_0 is the daily solar radiation outside the Earth's atmosphere. (joules per square meter per day)

T_{max} is the maximum daily ambient air temperature. (Degrees Celsius)

T_{min} is the minimum daily ambient air temperature. (Degrees Celsius)

a_4, b_4 an c_4 are empirical coefficients

IV. Research Results

The monthly average of the measurement stations using a statistical program to determine the trend of changes in solar radiation intensity over the 40-year period from 1951-2017, the consideration could be divided into two periods, the period before 1990 (1951-1990) and the period after 1990 (1990-2017). This was because the period in 1990 was when Thailand began to develop industrialization, thus affecting the increasing amount of aerosols in the atmosphere.

A. Changes in solar radiation intensity before 1990 (1951-1990)

The trend of change in solar radiation intensity of the central region during the period 1951-1990 showed no significant increase in mean annual solar radiation intensity. The trend slope estimate was 0.09142 and the mean was 221.14 W/m^2. For each season, there was no significant increase in the mean solar radiation intensity, except for the rainy season where there was a significant increase. The trend slope estimation lines were 0.08032, 0.30782, and 0.13016 at mean values of 247.05, 209.64, 206.51 W/m^2 in summer, rainy and winter respectively as shown in Table 1 and Fig. 1. If considering the average monthly solar radiation intensity, it was found that the highest solar intensity value of 260.98 watts per square meter is in April and the month with the lowest average solar radiation intensity of 194.97 W/m^2 was November as shown in Table 1 and Fig. 2.

Table 1 Estimates of trend line slope and average solar radiation intensity divided by yearly, seasonally and northern highest minimum in the years 1951-1990

	Estimation of the slope of the solar radiation intensity trend line	Average solar radiation intensity (W/m^2)
Yearly	0.09142	221.14
Summer	0.08032	247.05
Rainy season	0.30782*	209.64
Winter	0.13016	206.51
Month with the highest average		April (260.98)
Month with the lowest average		November (194.97)

* The trend was statistically significant at the 0.05 level.

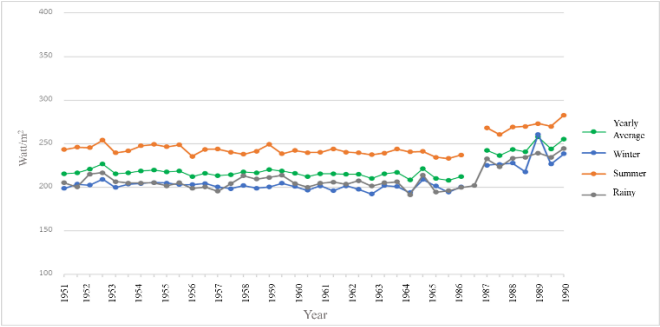


Fig. 1 Average annual and seasonal changes in solar radiation intensity in the central region in 1951-1990

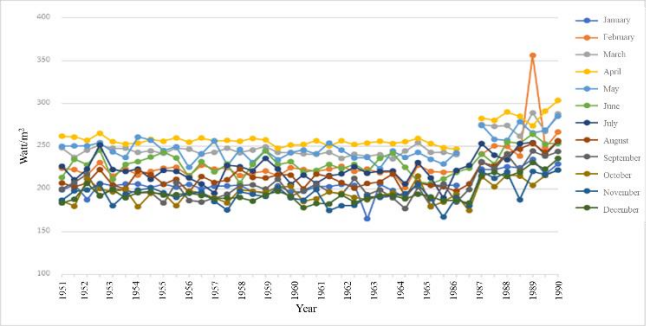


Fig. 2 Changes in the average monthly solar radiation intensity in the central region in 1951-1990

B. Trend of changes in solar radiation intensity after 1990

The annual average solar radiation intensity in the period after 1990 (1999-2017) showed a slight decrease in trend and averaged 199.36 W/m^2. The seasonal average solar radiation intensity was found that in summer, the highest average was 218.64 W/m^2, followed by winter and rainy season with averages of 186.95 and 187.56 W/m^2, respectively. There was a tendency to change the intensity of solar radiation significantly in the rainy season and winter. In summer, the intensity of solar radiation tends to decrease insignificantly as shown in Table 2 and Fig. 3. The average solar radiation intensity in April was the highest at 237.72 W/m^2 and the lowest average in December was 172.89 W/m^2 as shown in Fig. 4 and Table 2. The analysis revealed that the central region is facing a global dimming situation as the intensity of solar radiation tends to decrease.

Table 2 Mean solar radiation intensity and statistical test results of yearly and seasonal average solar radiation intensity in the northern region in 1991-2017

	Estimation of the slope of the solar radiation intensity trend line. (Q_{med})	Average solar radiation intensity (W/m^2)
Yearly	-0.510	199.36
Summer	-0.167	218.64
Rainy season	-0.560+	187.56
Winter	-0.900*	186.95
Month with the highest average		April (237.72)
Month with the lowest average		December (172.89)

Remark * The trend was statistically significant at the 0.05 level.

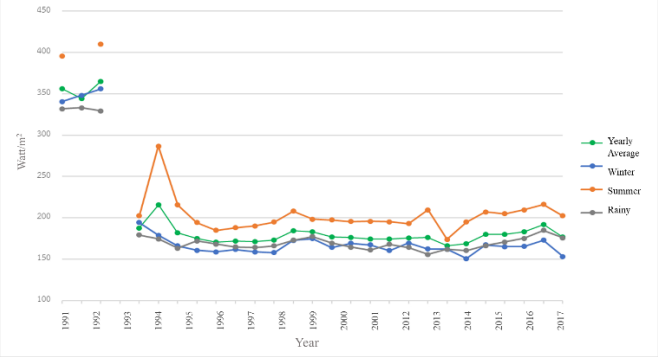


Fig. 3 Changes in average annual and seasonal solar radiation intensity in the central region in 1991-2017

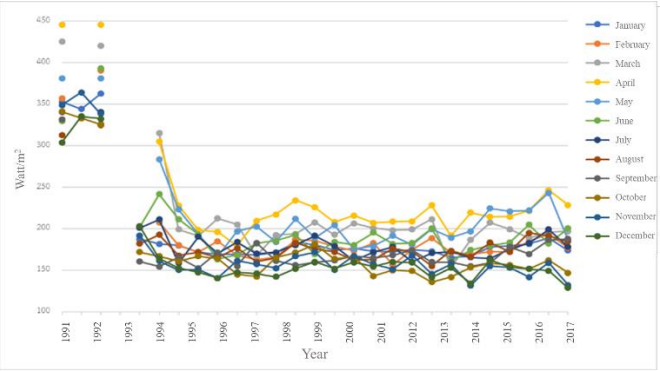
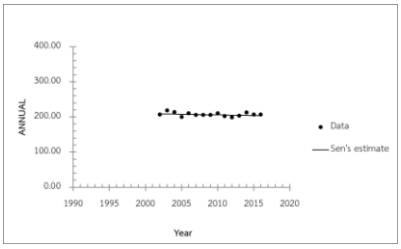
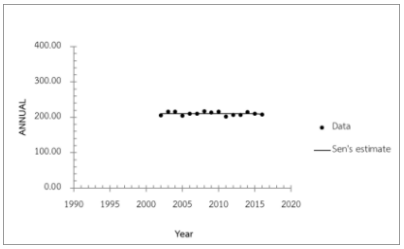
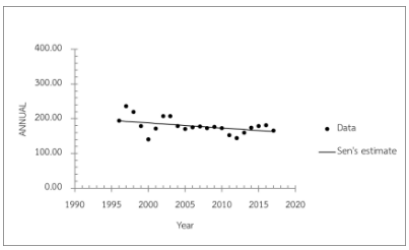
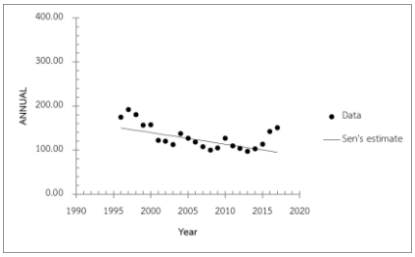
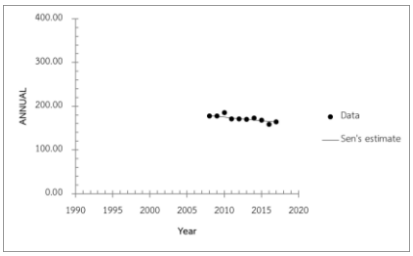


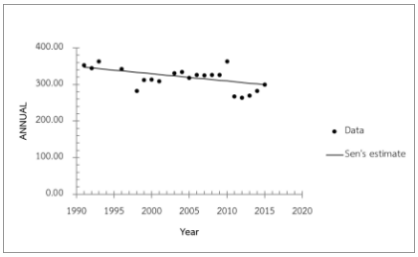
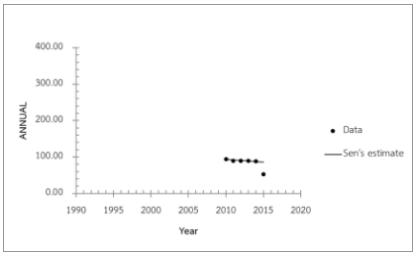
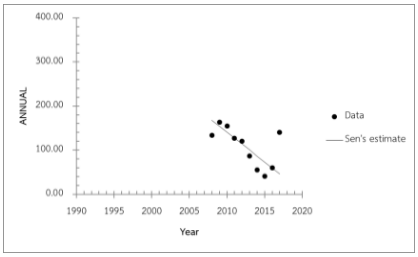
Fig. 4. Monthly average change in solar radiation intensity in the central region in 1991-2017

C. Changes in the trend of solar radiation by station after 1990

The results of the study could be summarized as a whole that the trend of solar radiation before 1990 was not significantly changed, while after 1990 there was a significant decline in terms of the local terrain and climate, as well as the density of buildings and traffic congestion in the area. Therefore, in this section, solar radiation trends must be considered in the period after 1990, as urbanization areas result in different types of dust and ash, which affected the intensity of solar radiation. Table 5 showed the estimation of the trend slope of central light from rural stations. It was found that the trend of solar radiation intensity at Nakhon Sawan Station (-0.332) and Lopburi Station (-0.081) was significantly reduced. While the trend slope estimate of the solar radiation intensity in urban areas decreased, the slope of the trendline was lower than in rural areas. Urbanization was more concentrated and produces higher air pollution than rural areas such as Khlong Chan Community Housing Station (-1.484), Wat Sing School (Singharat Pittayakom) (-2.643), South Bangkok Power Plant Station (-1.640), Bangkok - Bangna Station (-1.982), Silpakorn Station, Nakhon Pathom (-1.526) and Samut Prakan City Hall Station (-13.555). It may be noted that the slope estimates for the solar radiation trend line were significantly reduced because Samut Prakan was a highly industrialized area and an extension from Bangkok. As a result of this situation, there was a large amount of pollutants in the air and affects the transmittance of solar radiation that hit the earth's surface.

Table 5 Estimated trend slope of solar radiation intensity after 1990

Province (city/rural)	Estimated trend slope of sunlight after 1990
Nakhon Sawan (rural) Q_{med} = -1.640*	
Lop Buri (rural) Q_{med} = -0.081	
Bangkok (City: Khlong Chan Community Housing Station) Q_{med} = -1.484*	
Bangkok (City: Wat Sing School (Singharat Pittayakom)) Q_{med} = -2.643*	
Samut Prakan (City: South Bangkok Power Plant Station) Q_{med} = -1.640*	

Province (city/rural)	Estimated trend slope of sunlight after 1990
Bangkok (City: Bangkok - Bangna Station) Q_{med} = -1.982*	
Nakhon Pathom (City: Silpakorn Station, Nakhon Pathom) Q_{med} = -1.526*	
Samut Prakan (City: Samut Prakan City Hall Station) Q_{med} = -13.555*	

Remark* Sig.=0.05

Measures should be taken to deal with the global dimming situation in central Thailand seriously to reduce or alleviate air pollution from transportation and industrial sectors, especially in large urban areas such as Bangkok and nearby provinces located in the central region of Thailand. Reducing private vehicle use, optimizing public transport, and relocating or limiting activities that attract non-urban travel to city centers such as moving wholesale markets away from urban centers, enforcing fiscal measures on taxation, preserving the environment from pollution sources and increasing urban green spaces should be taken into serious consideration [15]. In addition, the management of land covers by means of proper roadside planting and pushing of air pollution problems is an urgent issue of the country.

V. Discussions

The study found that in the country as a whole, the trend of the average annual solar radiation intensity before 1990 from the average daily total irradiance estimate model did not change significantly. Before 1990, the country was preparing for the country's development by setting up the country's main city infrastructure such as transportation systems, irrigation systems, electrical systems and various energy systems, including industrial investment policies, but not very intensive in practice. Therefore, before 1990, there was no dust and other pollutants from human activities that were the main cause of the decrease in solar radiation, thus global dimming was not seen during this period. Comparatively, the nature of the change in solar radiation with other regions found that in Europe data on global dimming phenomena have been reported. The annual mean solar radiation intensity had declined since before 1960 [16] [17] [18] [19] [20]. The main reasons for the decrease in solar radiation on Earth's surface in Europe could be summarized. [2] was indicated that the changes in aerosols were mainly due to 1) the increase in industrialization and aerosols as a product of urbanization. 2) The change in terrestrial solar radiation varies with the latitude in relation to the pollution source. According to the findings, estimates of terrestrial solar radiation were compared with estimates of fossil fuel emissions at latitude during the 1960-1990s. The latitudes showing a decrease in Earth's solar radiation and an increase in fuel emissions were approximately 35 degrees north latitude, corresponding to areas of high industrial activity and very dense populations.

According to the air quality monitoring station, the country's annual average solar radiation intensity trend after 1990 showed a significant decline at 0.01 levels. Such results could be concluded that the central region is entering global dimming as solar radiation intensity tends to decrease. Compared to the situation in other regions, data from Europe after 1990 reported that Europe had shifted to the "Brightening Period", that is, surface solar radiation tended to increase [21] [22] [23] [24] because of the measures to reduce pollution of European countries and the relocation of industrial production bases to developing countries. Thailand was one of the areas for industrial development. This action began with the policy to promote industrial development from the 3rd National Economic and Social Development Plan (1972–1976) that clearly defined directions and objectives in the field of industrial development. In this regard, it was the clear start of industrial development and the most intense development in the 6th National Economic and Social Development Plan (1987–1991). Thus, it could be said that a global dimming situation in the central region is under development without effective air pollution control measures.

CONCLUSION

Global dimming is a phenomenon in which the intensity of the solar radiation hitting the Earth's surface decreases. The situation had been gaining attention since 1950 and the intensity of solar radiation that hit the Earth's surface tended to decline until 1990, especially in industrialized countries. This was due to the high industrialization of the period, which was the main cause of the emission of pollutants into the atmosphere and the blocking of the sun's rays from reaching

the earth until the situation had the opposite effect after 1990. The intensity of solar radiation tends to be higher in developed countries because during that time, industrial production bases were moved to developing countries. Therefore, it was generally accepted that the situation of the change in intensity of solar radiation that hit the Earth's surface was divided by the time of the "Dimming Period" in pre-1990 and a situation called "Brightening Period" in pre-1990.

The results of a study on the trend of solar radiation intensity of the country in 1990 were used to study the change and analyze the situation of the change in the intensity of solar radiation that hits the earth's surface. The study of the trend of solar radiation intensity and the intensity of solar radiation that hits the earth's surface by considering the solar radiation estimation model and air quality monitoring station found that overall, the central region of Thailand had no significant change in the average annual solar radiation intensity prior to 1990 because in the period before 1990, Thailand was preparing to develop the country by setting up infrastructure systems in Bangkok and the main cities of the country such as transportation systems, irrigation systems, electrical systems and various energy systems, including industrial investment policies and were considered to be in the range of non-intensive practice. Therefore, before 1990, there was not much dust and various pollutants from human activities that caused the reduction of solar radiation. According to the air quality monitoring station, in the period after 1990, the country's annual average solar radiation intensity trend was estimated to decrease the slope of the trend line. It could be concluded that the central region of Thailand is in global dimming because the intensity of solar radiation tends to decrease. If considering the season that affects the intensity of solar radiation found that in winter, the intensity of solar radiation was significantly reduced.

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