Scientific Review – Engineering and Environmental Sciences (2021), 30 (2), 236–249
Sci. Rev. Eng. Env. Sci. (2021), 30 (2)
Przegląd Naukowy – Inżynieria i Kształtowanie Środowiska (2021), 30 (2), 236–249
Prz. Nauk. Inż. Kszt. Środ. (2021), 30 (2)
http://iks.pn.sggw.pl
DOI 10.22630/PNIKS.2021.30.2.20

Winai SURIYA, Poramate CHUNPANG, Teerawong LAOSUWAN
Mahasarakham University, Faculty Science

Patterns of relationship between PM_{10} from air monitoring quality station and AOT data from MODIS sensor onboard of Terra satellite

Key words: remote sensing, MODIS sensor, PM_{10}, aerosol optical thickness (AOT), air quality index (AQI)

Introduction

Currently, Thailand, especially in the northern region, is encountering air pollutions due to smokes, accumulation of smokes or dust in the air, which are mostly caused by the burning of forest area and open area for agricultural purpose. Also, the terrains in many areas in the northern region are characterized by "pan" shape, with plain areas surrounded by mountains, and the weather is quite still and dry for a long period of time; these are the reason of the accumulation of pollution which cannot be ventilated, therefore, the concentration of pollution is quite high especially in the urban area. This causes such area to encounter the problem of air pollution (Suwanprasit, Charoenpanyanet, Pardthaisong & Sinampol, 2018). Also, there are other causes including more transportation, more burning of forest area and open area (Supasri, Intra, Jomjunyong & Sampattagul, 2018).

Particulate matter (PM) is the particles consisting of nitrogen oxide (NO_x), sulfur dioxide (SO_2), ammonia (NH_3), polycyclic aromatic hydrocarbons (PAHs) which are combined and floating in the air in form of dust; it can be divided by size – the one smaller than 2.5 µm, is called $PM_{2.5}$, and the one smaller than 10 µm is called PM_{10} (Porter & Clarke, 1997; Meng et al., 2019). Dust is the pollution that mostly affects human than other air pollutions. Particulate matter comes from both nature such as soil dust, sand dust, and from the matter on the ground blown by wind, smoke from wild fire, salty particles from seawater and comes from human activities such as dust from construction, dust from transportation on road, smoke released from exhaust pipe of car and motorcycle, dust and smoke from chimney from crematorium, incinerator of industrial plant, and the burning of agricultural residues in open area (Pollution Control Department [PCD], 2004; Nathapindhu, Sttheetham & Ketkowit, 2011; World Health Organization [WHO], 2017). The danger of dust traveling into the respiratory system depends on the size, quantity, chemical properties, and biological qualities. Dust, once travelling into the respiratory system, would accumulate in various parts of the respiratory system, depending on its size; the rough dust would be filtered by nose hair and thus falling onto the primary respiratory system, and the fine dust and the very fine dust would pass into the bronchus, bronchiole, and deep into the alveoli. If a large quantity of dust is inhaled, it would affect health a lot accordingly (Adams, Greenbaum, Shaikh, van Erp & Russel, 2015; GreenFacts, 2018; United States Environmental Protection Agency [USEPA], 2018).

Particulate matter PM_{10} is the serious problem of air pollution in the northern region, which is mostly caused by the burning of forest area and open area and is clearly seen during January–April of every year (Amphanthong & Busababodhin, 2015). The monitoring of PM_{10} quantity can be done by the inspection performed at the Ground Monitoring Station of Pollution Control Department (PCD) and the Thai Meteorological Department (TMD); it is not possible to install the station in all critical areas due to the fact that the air monitoring device is large, the expense spent in the operation and maintenance is high, and in some monitoring stations it is not possible to perform real-time monitoring which results in the limitation on the monitoring of dust in terms of space and time (Outapa & Ivanovitch, 2019). However, the problem related to dust or PM in the northern region needs to be solved immediately.

According to the related researches, it was found that at present, the remote sensing technology was applied by using data received from the satellite in monitoring and following the air quality situations (Liu, Sarnat, Kilaru, Jacob & Koutrakis, 2005; Kloog, Koutrakis, Coull, Lee & Schwartz, 2011; Nguyen, Cressie & Braverman, 2012; Benas, Beloconi & Chrysoulakis, 2013; Vienneau et al., 2013; Phayungwiwatthanakoon, Suwanwaree & Dasamanda 2014; He & Huang, 2018). The remote sensing is the modern and efficient technology that can be applied to monitor and inspect various phenomena on Earth in time (Sukitpaneenit & Oanh, 2014; Emetere, Sanni, Okoro & Adeyemi, 2018; Rotjanakusol & Laosuwan, 2018, 2019; Uttaruk & Laosuwan, 2019). Due to the importance of monitoring and following up the air quality circumstance, this study aims to find patterns of relationship between PM_{10} from the air quality station and AOT data received from MODIS sensor onboard of Terra satellite in Phrae Province, the northern region of Thailand.

Studying area and satellite data

Studying area. Phrae Province (Fig. 1) is located in the northern region of Thailand, with the area of 6,538.59 km^2, between the latitude of 17.70° to 18.84°N to the longitude of 99.58° to 100.32°E; it is 155 m high from moderate sea level. The province is surrounded by mountains in four directions; most of the area, about 80%, are mountainous with the plain area of only 20%. The average air temperature in Phrae in the whole year is about 26.4°C, with the average minimum temperature of 21.6°C and with average maximum temperature of 33.2°C.

Data used in the study. Data of Moderate Resolution Imaging Spectroradiometer (MODIS) sensors, the aerosol optical thickness (AOT) on land and ocean would be of the Level 2 Product with the resolution of the image of 10×10 km^2 at and is the near-real-time product data. Therefore, in this study, the data from MODIS sensor onboard of Terra satellite was applied with the code of MODO4_L2 Aerosol Product (Optical_Depth_Land_And_Ocean). The MODO4_L2 Aerosol Product file covers a five-minute time interval. The

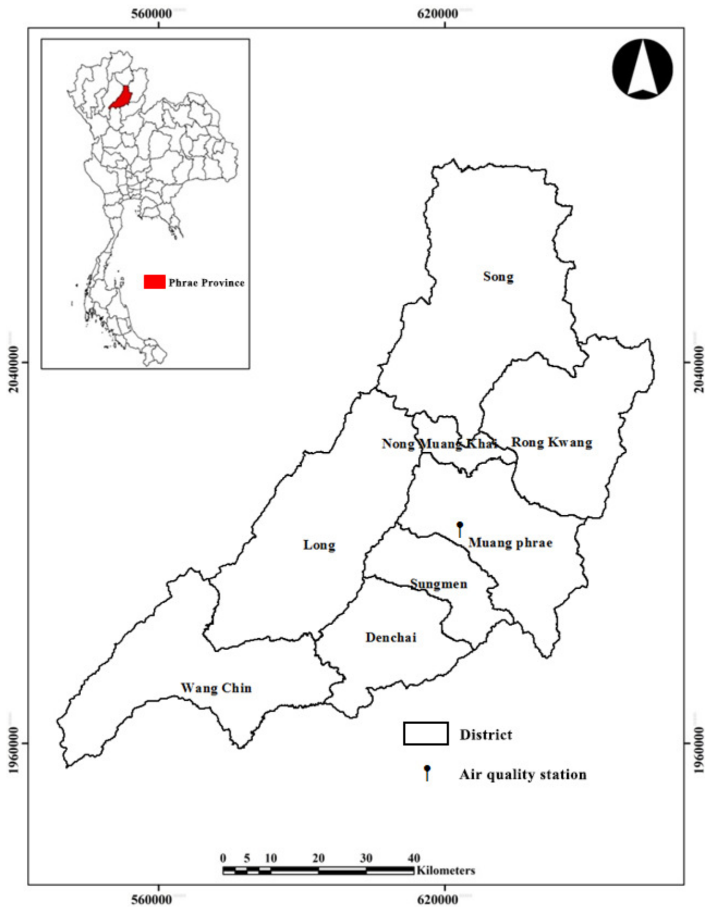

FIGURE 1. Phrae Province, the northern region of Thailand

output grid is 135 pixels in width by 203 pixels in length. Every tenth file has an output grid size of 135 by 204 pixels. The MOD04_L2 Aerosol Product files are stored in hierarchical data format (HDF). The data was downloaded from web interface LAADS DAAC (https://ladsweb.modaps.eosdis.nasa.gov); the duration of 10.00–11.00 am at local time was selected when the MODIS sensor onboard of Terra satellite orbit passes Thailand. Data used were on daily basis from 1st January to 30th April 2018.

Ground temperature data. In this study, the data of PM_{10} on hourly basis was collected in the period from 1st January to 30th April 2018 during 10.00–11.00 am from the air quality station of the air4thai (http://air4thai.pcd.go.th/webV2) located at Mueang District, Phrae Province, located Na Chak Subdistrict, Mueang District, Phrae Province, with the latitude of 18.13°N and longitude of 100.16°E.

Methodology

Since AOT data received from MODIS sensor onboard of Terra satellite is in HDF or granule coverage, so before analyzing AOT data, it is necessary to adjust the projection systems by georeference. In this study, the projection systems were determined to be UTM WGS-84 zone 47; after that, the adjusted data were brought for numerical analysis of AOT further. In this research, the correlation analysis using software package was performed (Eq. 1) to study the relationship between PM_{10} quantity from the air quality station of the air4thai with the AOT data received from Terra MODIS satellite.

$$r = \frac{\sum \left(X_i - \overline{X}\right)\left(Y_i - \overline{Y}\right)}{\sqrt{\sum \left(X_i - \overline{X}\right)^2 \sum \left(Y_i - \overline{Y}\right)^2}} \qquad (1)$$

where:
$r = 1$ – perfect positive correlation,
$r = -1$ – perfect negative correlation.

The result of the analysis would yield correlation coefficient (r) which indicated the extent of relationship of the data, for linear regression analysis (Eq. 2), which is one statistical method for examining the relationship between two or more variables; this is divided into independent variable x and dependent variable y. In this research, x is PM_{10} quantity from the air quality station of the air4thai and y is AOT data received from MODIS sensor onboard of Terra satellite at the coordinate of the ground monitoring station.

$$y = ax + b \qquad (2)$$

where:
x – independent variable,
y – dependent variable.

Besides, PM_{10} quantity obtained from the monitoring station was brought to replace the value in the linear regression equality of each month in order to see the density of PM_{10} in spatial term. Finally, the distribution map of PM_{10} was created in spatial term under AQI which is the report on the weather in simple and easy-to-understand form in order to disseminate such data to the public so that they could be informed of the air pollution situations. Various countries would have their own AQI – Thailand in this study.

Result of the study

The results of the analysis into the relationship between PM_{10} and AOT by using statistical method that is correlation analysis are shown in Table 1. According to Table 2, it was found that in overall, PM_{10} and AOT are highly related, with the correlation coefficient in January of $r = 0.928$, in February of $r = 0.919$, in March of $r = 0.916$, and in April of $r = 0.927$. The results of the linear regression analysis of duration between January and April are shown in Figures 2–5. In January, the data collection from MODIS sensor onboard of Terra satellite (AOT) and air quality stations (PM_{10}) was shown in Table 2.

TABLE 1. Correlation coefficient (r) between PM_{10} and AOT in Thailand in 2018 in selected months

Month	r
January	0.928
February	0.919
March	0.916
April	0.927

From Figure 2, it shows the relationship between the quantity of PM_{10} and AOT in January of Phrae Province; when PM_{10} increased, AOT would increase accordingly. On the contrary, when PM_{10} decreased, AOT would also decrease. According to the linear regression analysis, it was found that the minimum PM_{10} was 30 $\mu g \cdot m^{-3}$ and maximum PM_{10} was 79 $\mu g \cdot m^{-3}$. The linear regression equality $y = 97.679x - 0.7215$ and the coefficient in making decision of r^2 was 0.983.

In February, the data collection from MODIS sensor onboard of Terra satellite (AOT) and air quality stations (PM_{10}) was shown in Table 3.

TABLE 2. Data collected from MODIS sensor onboard of Terra satellite and the air quality stations in Thailand in January 2018

Date	AOT	PM_{10} [$\mu g \cdot m^{-3}$]
5	0.309	30
6	0.325	31
7	0.358	34
8	0.601	59
9	0.481	45
10	0.449	42
11	0.426	41
12	0.384	36
14	0.393	36
15	0.452	44
16	0.391	38
17	0.486	46
18	0.479	43

Date	AOT	PM_{10} [$\mu g \cdot m^{-3}$]
19	0.408	41
20	0.457	46
21	0.498	48
22	0.553	52
23	0.715	71
24	0.708	70
25	0.562	55
26	0.821	79
27	0.801	76
28	0.547	57
29	0.485	49
30	0.491	45
31	0.624	57

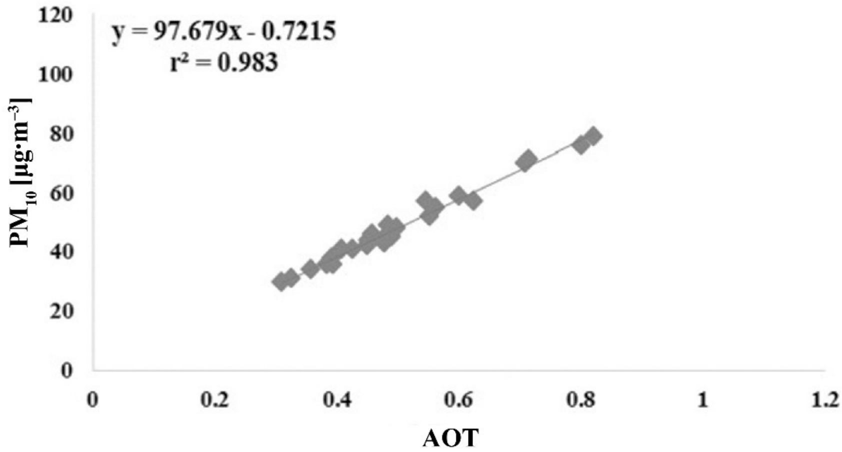

FIGURE 2. Linear regression between PM_{10} and AOT in Thailand in January 2018

TABLE 3. Data collected from MODIS sensor onboard of Terra satellite (AOT) and the air quality stations (PM_{10}) in Thailand in February 2018

Date	AOT	PM_{10} [$\mu g \cdot m^{-3}$]
1	0.603	61
2	0.521	51
3	0.694	68
4	0.635	62
5	0.782	75
6	0.891	86
7	0.973	91
8	0.987	96
9	1.108	102
10	0.921	93
11	0.902	94
12	0.915	97
13	0.841	81

Date	AOT	PM_{10} [$\mu g \cdot m^{-3}$]
14	0.726	71
15	0.887	89
16	0.862	84
17	0.712	70
18	0.631	68
19	0.993	97
20	0.922	93
21	0.876	85
23	0.472	44
25	0.486	47
26	0.553	52
28	0.476	48

From Figure 3, it shows the relationship between the quantity of PM_{10} and AOT in February of Phrae Province; when PM_{10} increased, the AOT would increase accordingly. On the contrary, when PM_{10} decreased, AOT would also decrease. According to the linear regression analysis, it was found that the minimum PM_{10} was 44 $\mu g \cdot m^{-3}$ and maximum PM_{10} was 102 $\mu g \cdot m^{-3}$. The linear regression equality $y = 96.643x + 1.3248$ and the coefficient in making decision of r^2 was 0.9719.

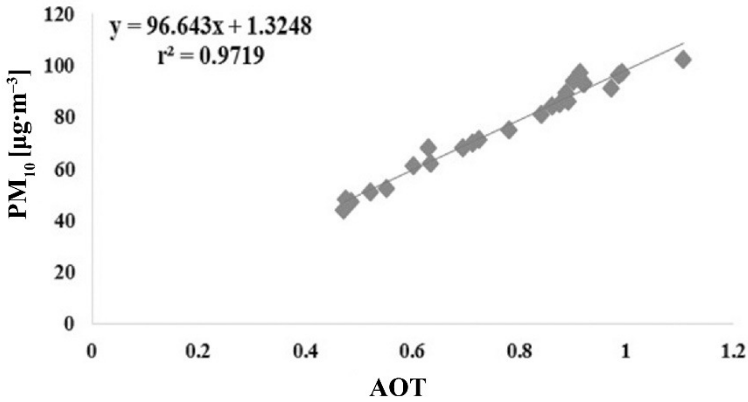

FIGURE 3. Linear regression between PM_{10} and AOT in Thailand in February 2018

In March, the data collection from Terra MODIS satellite (AOT) and air quality stations (PM_{10}) was shown in Table 4.

From Figure 4, it shows the relationship between the quantity of PM_{10} and AOT in March of Phrae Province; when PM_{10} increased, the AOT would increase accordingly. On the contrary, when PM_{10} decreased, AOT would also decrease. According to the linear regression analysis, it was found that the minimum PM_{10} was 58 $\mu g \cdot m^{-3}$ and maximum PM_{10} was

TABLE 4. Data collected from Terra MODIS satellite (AOT) and the air quality stations (PM_{10}) in Thailand in March 2018

Date	AOT	PM_{10} [$\mu g \cdot m^{-3}$]	Date	AOT	PM_{10} [$\mu g \cdot m^{-3}$]
2	0.587	76	18	0.681	86
3	0.596	77	19	0.807	98
4	0.773	93	20	0.954	112
5	1.064	118	21	1.136	132
6	1.663	184	22	0.975	101
7	1.134	139	23	0.682	88
8	0.981	112	24	0.691	88
9	0.394	58	25	0.741	91
11	0.403	59	26	0.809	100
13	0.449	63	27	0.748	92
14	0.561	76	28	0.759	92
15	0.846	107	29	0.862	102
16	0.908	112	30	0.754	93
17	0.795	97	31	0.783	91

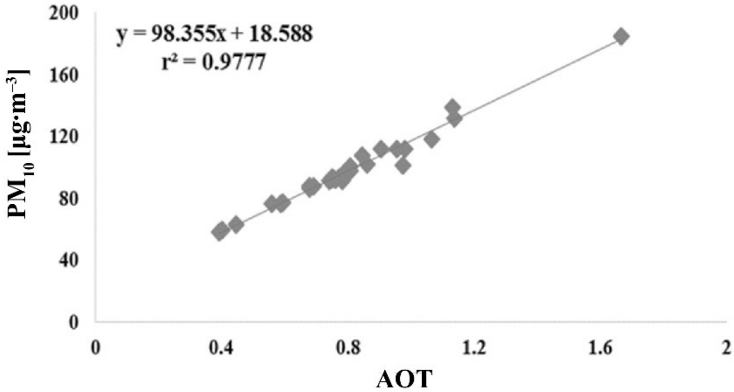

FIGURE 4. Linear regression between PM_{10} and AOT in Thailand in March 2018

184 µg·m^{-3}. The linear regression equality y = 98.335x + 18.588 and the coefficient in making decision of r^2 was 0.9777.

In April, the data collection from MODIS sensor onboard of Terra satellite (AOT) and air quality stations (PM_{10}) was shown in Table 5.

From Figure 5, it shows the relationship between the quantity of PM_{10} and AOT in April of Phrae Province; when PM_{10} increased, AOT would increase accordingly. On the contrary, when PM_{10} decreased, AOT would also decrease. According to the linear regression analy-

TABLE 5. Data collected from MODIS sensor onboard of Terra satellite (AOT) and the air quality stations (PM_{10}) in Thailand in March 2018

Date	AOT	PM_{10} [µg·m^{-3}]
1	0.782	56
2	0.754	52
3	0.761	50
4	0.857	66
5	0.731	53
7	0.586	37
9	0.706	51
10	0.701	47
11	0.864	65
12	0.947	78
13	1.065	84
14	1.075	82
15	1.063	85
16	0.725	54
17	0.526	32
19	0.572	37
20	0.754	56
21	0.952	74
22	1.132	90
23	1.053	87
24	1.204	99
25	1.426	114
26	0.857	65
27	0.535	32
28	0.554	31
29	0.493	21
30	0.482	24

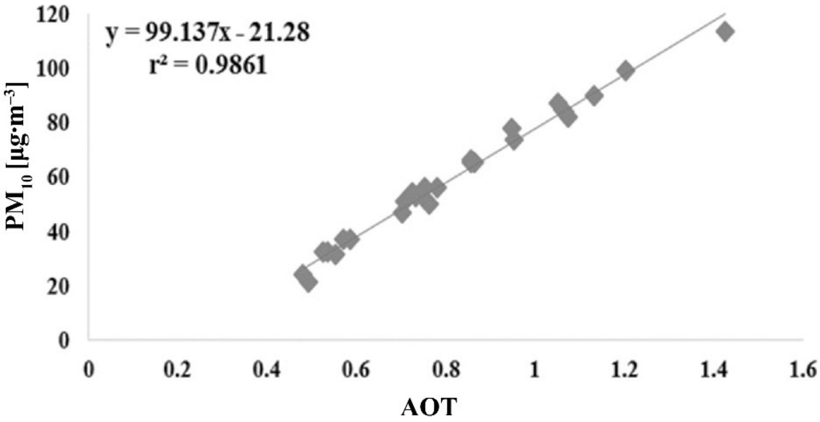

FIGURE 5. Linear regression between PM_{10} and AOT in Thailand in April 2018

sis, it was found that the minimum PM_{10} was 21 $\mu g \cdot m^{-3}$ and maximum PM_{10} was 114 $\mu g \cdot m^{-3}$. The linear regression equality $y = 99.137x - 21.28$ and the coefficient in making decision of r^2 was 0.9861.

Furthermore, the result of the distribution map creation of PM_{10} in spatial term under AQI of Thailand (Table 6) to show that whether PM_{10} has effect on the health or not can be seen from the entire Figure 6. According to Figure 6a, it was found that Phrae Province had air of good quality and moderate quality in January; the people can do outdoor activities and tour normally. From Figure 6b, it was found that Phrae Province had good quality of air and moderate quality of air and the quality of air affected the health in February. The people who live in the blue area and green area can do outdoor activities and tour normally; and the people who live in yellow zone can do outdoor activities normally except for someone who is vulnerable was found to have primary symptom such as cough, being hard to breathe, eye irritation; so, the period of time to do outdoor activities should be reduced. According to Figure 6c, it was found that Phrae Province had moderate quality and the quality of air affected the health in March. The people who live in the blue area and green area can do outdoor activities and tour normally; and the people who live

TABLE 6. Criteria for AQI in Thailand

AQI	PM_{10} [$\mu g \cdot m^{-3}$]	Levels of health concern	Colors
0–25	0–50	very good	blue
26–50	51–80	good	green
51–100	81–120	moderate	yellow
101–200	121–180	unhealthy	orange
> 201	181	very unhealthy	red

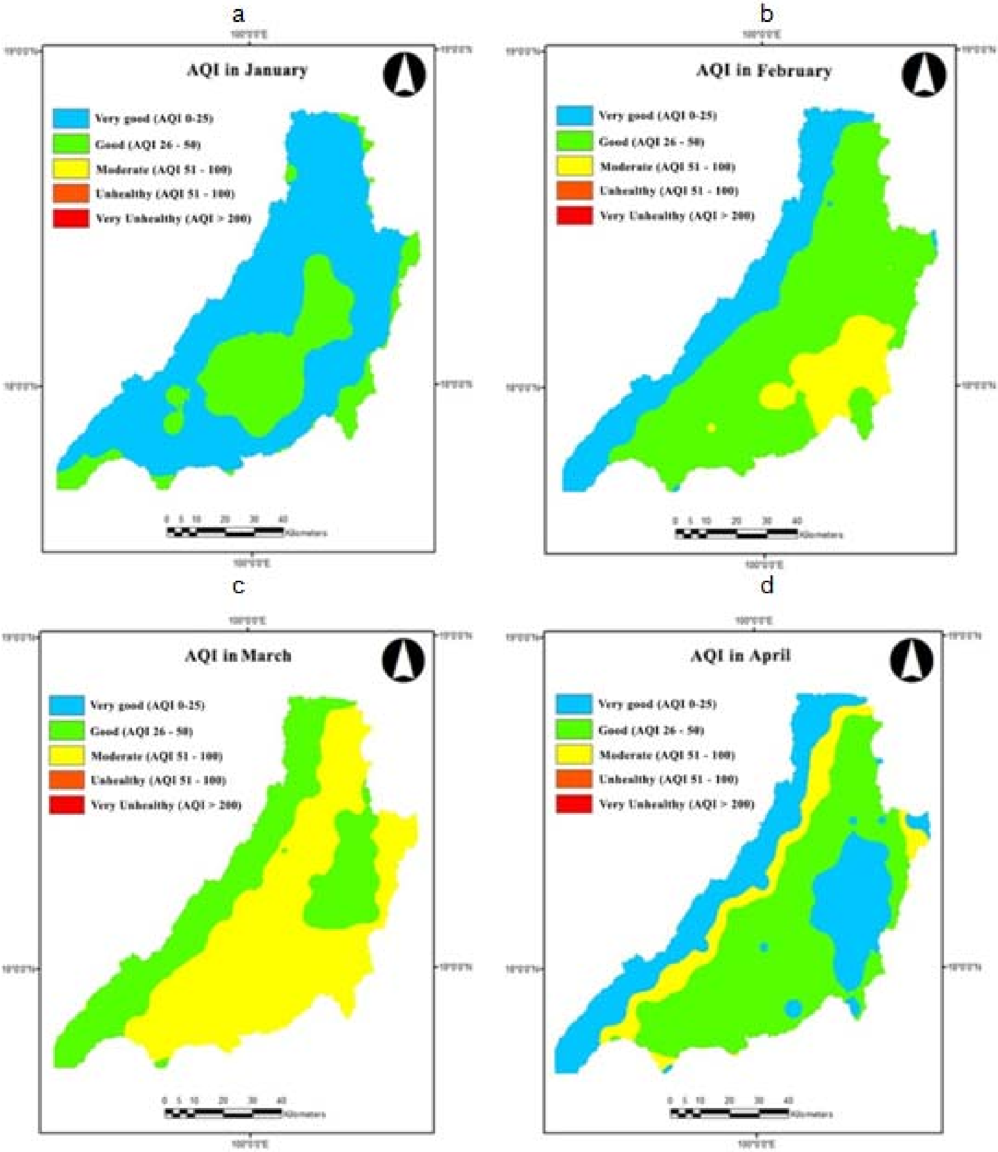

FIGURE 6. The air quality index in Thailand in 2018 in selected months: a – January; b – February; c – March; d – April

in yellow zone can do outdoor activities normally except for someone who is vulnerable was found to have primary symptom such as cough, being hard to breathe, eye irritation; so, the period of time to do outdoor activities should be reduced. From Figure 6d, it was found that Phrae Province had good quality of air and moderate quality of air and the quality of air affected the health in April.

The people who live in the blue area and green area can do outdoor activities and tour normally; and the people who live in yellow zone can do outdoor activities normally except for someone who is vulnerable was found to have primary symptom such as cough, being hard to breathe, eye irritation; so, the period of time to do outdoor activities should be reduced.

In addition, PM_{10} is a major air pollution problem in Northern Thailand. The problem is evident during the dry season from December to April each year. As a result of this study, it was found that the most common problem of PM_{10} was in March, during which time. However, the main causes of PM_{10} in Northern Thailand are caused by open-air burning activities, forest fires, agricultural waste incineration, incineration, and the occurrence of forest fires in neighboring countries.

Conclusions

According to the study into the pattern of relationship between PM_{10} from the ground monitoring station of the air4thai with AOT data received from MODIS sensor onboard of Terra satellite in Phrae Province, the northern region of Thailand during January–April 2018, it was under the objective. It was found from the research that in March, PM_{10} was highest equal to 184 $\mu g \cdot m^{-3}$. In January, where PM_{10} was lowest was equal to 79 $\mu g \cdot m^{-3}$; the change of PM_{10} quantity and AOT was highly related (near 1) in every month. Besides, when the linear regression analysis was performed, it was found that independent variable (x) and dependent variable (y) were consistent, with the coefficient of decision of r^2 being near 1 in every month also. In February–April period in Phrae Province, it was the time when quantity of PM_{10} affected health according to the AQI standard of Thailand. In addition, the result from this research was consistent and was in the same direction with the research on "Satellite measurements of aerosol optical depth and carbon monoxide and comparison with ground data" by Lalitaporn and Mekaumnuaychai (2020), which indicated PM_{10}. High levels of PM_{10} occur more frequently from March to April. Furthermore, PM_{10} is higher in the morning than in the afternoon.

In bringing AOT data obtained from MODIS sensor onboard of Terra satellite to be applied in this research, the advantage was that this was near-real-time data and covered wide area (10 × 10 km^2 per 1 pixel). However, AOT data were classified by passive remote sensing system, with disadvantage of that in some days, there might be cloud over the area making it impossible to monitor AOT quantity. On part of PM_{10} data from the ground monitoring station, the advantage was that it was PM_{10} which was monitored by direct sensor; but with disadvantage that was that the PM_{10} monitoring tool cannot be installed in the station of all critical area since such air monitoring tool is large and the budget to be spent on the operation and the maintenance is high.

Acknowledgements

This research was financially supported by Mahasarakham University (Grant year 2021).

References

Adams, K., Greenbaum, D.S., Shaikh, R., Erp, A.M. van & Russell, A.G. (2015). Particulate matter components, sources, and health: Systematic approaches to testing effects. *Journal of the Air & Waste Management Association*, *65*(5), 544-558. https://doi.org/10.1080/10962247.2014.1001884

Amphanthong, P. & Busababodhin, P. (2015). Forecasting PM_{10} in the Upper Northern Area of Thailand with Grey System Theory. *Burapha Science Journal*, *20*(1), 15-24.

Benas, N., Beloconi, A. & Chrysoulakis, N. (2013). Estimation of urban PM_{10} concentration, based on MODIS and MERIS/ /AATSR synergistic observations. *Atmospheric Environment*, *79*, 448-454. https://doi.org/10.1016/j.atmosenv.2013.07.012

Emetere, M.E., Sanni, S.E., Okoro, E.E. & Adeyemi, G.A. (2018). Aerosol loading and its effect on respiratory dysfunction disorder over Dapaong-Togo. *Scientific Review Engineering and Environmental Sciences*, *27*(4), 410-424. https://doi.org/10.22630/PNIKS.2018.27.4.40

GreenFacts (2018). *Air pollution particulate matter*. Retrieved from: https://www.greenfacts.org/en/particulate-matter-pm/level-2/01-presentation.htm [access 15.08.2020].

He, Q. & Huang, B. (2018). Satellite-based mapping of daily high-resolution ground $PM_{2.5}$ in China via space-time regression modeling. *Remote Sensing of Environment*, *206*, 72-83. https://doi.org/10.1016/j.rse.2017.12.018

Kloog, I., Koutrakis, P., Coull, B.A., Lee, H.J. & Schwartz, J. (2011). Assessing temporally and spatially resolved $PM_{2.5}$ exposures for epidemiological studies using satellite aerosol optical depth measurements. *Atmospheric Environment*, *45*(35), 6267-6275. https://doi.org/10.1016/j.atmosenv.2011.08.066

Lalitaporn, P. & Mekaumnuaychai, T. (2020). Satellite measurements of aerosol optical depth and carbon monoxide and comparison with ground data. *Environmental Monitoring and Assessment*, *192*, 369. https://doi.org/10.1007/s10661-020-08346-7

Liu, Y., Sarnat, J.A., Kilaru, V., Jacob, D.J. & Koutrakis, P. (2005). Estimating ground-level $PM_{2.5}$ in the eastern United States using satellite remote sensing. *Environmental Science & Technology*, *39*(9), 3269-3278. https://doi.org/10.1021/es049352m

Meng, X., Wu, Y., Pan, Z., Wang, H., Yin, G. & Zhao, H. (2019). Seasonal Characteristics and Particle-size Distributions of Particulate Air Pollutants in Urumqi. *International Journal of Environmental Research and Public Health*, *16*(3), 396. https://doi.org/10.3390/ijerph16030396

Nathapindhu, G., Sttheetham, D. & Ketkowit, K. (2011). Public Participation in Open Burning Control. *KKU Research Journal*, *16*(4), 408-415.

Nguyen, H., Cressie, N. & Braverman, A. (2012). Spatial statistical data fusion for remote sensing applications. *Journal of the American Statistical Association*, *107*(499), 1004-1018. https://doi.org/10.1080/01621459.2012.694717

Outapa, P. & Ivanovitch, K. (2019). The effect of seasonal variation and meteorological data on PM_{10} concentrations in Northern Thailand. *International Journal of GEOMATE*, *16*(56), 46-53. https://doi.org/10.21660/2019.56.4558

Phayungwiwatthanakoon, C., Suwanwaree, P., Dasananda, S. (2014). Application of new MODIS-based Aerosol Index for Air Pollution Severity Assessment and Mapping in Upper Northern Thailand. *Environment Asia*, *7*(2), 133-141. https://doi.org/10.14456/ea.2014.32

Pollution Control Department [PCD] (2004). *Air pollution*. Retrieved from: http://www.pcd.go.th/ info_serv/air_dust.htm [access 04.05.2020].

Porter, J.N. & Clarke, A.D. (1997). Aerosol size distribution models based on in situ measurements. *Journal of Geophysical Research Atmospheres*, *102*(D5), 6035-6045. https://doi.org/10.1029/96JD03403

Rotjanakusol, T. & Laosuwan, T. (2018). Estimation of land surface temperature using Landsat satellite data: a case study of Mueang Maha Sarakham District, Maha Sarakham Province, Thailand for the years 2006 and 2015. *Scientific Review Engineering and Environmental Sciences*, *27*(4), 401-409. https://doi.org/10.22630/PNIKS.2018.27.4.39

Rotjanakusol, T. & Laosuwan, T. (2019). *Drought Evaluation* with *NDVI-Based Standardized Vegetation Index* in *Lower Northeastern Region* of *Thailand. Geographia Technica, 14(1), 118-130*. https://doi.org/10.21163/GT_2019.141.09

Sukitpaneenit, M. & Oanh, N.T.K. (2014). Satellite monitoring for carbon monoxide and particulate matter during forest fire episodes in Northern Thailand. *Environmental Monitoring and Assessment*, *186*(4), 2495-2504. https://doi.org/10.1007/s10661-013-3556-x

Suwanprasit, C., Charoenpanyanet, A., Pardthaisong, L. & Sin-ampol, P. (2018). Spatial and temporal variations of satellite-derived PM_{10} of Chiang Mai: an exploratory analysis. *Procedia Engineering*, *212*, 141-148. https://doi.org/10.1016/j.proeng.2018.01.019

Supasri, T., Intra, P., Jomjunyong, S. & Sampattagul, S. (2018). Evaluation of Particulate Matter Concentration by Using a Wireless Sensor System for Continuous Monitoring of Particulate Air Pollution in Northern of Thailand. *Journal of Innovative Technology Research*, *2*(1), 69-83.

United States Environmental Protection Agency [USEPA] (2018). Particulate Matter (PM) Pollution. Retrieved from: https://www.epa.gov/pm-pollution/particulate-matter-pm-basics [access 20.01.2020].

Uttaruk, Y. & Laosuwan, T. (2019). Drought Analysis Using Satellite-Based Data and Spectral Index in Upper Northeastern Thailand. *Polish Journal of Environmental Studies*, *28*(6), 4447-4454. https://doi.org/10.15244/pjoes/94998

Vienneau, D., Hoogh, K. de, Bechle, M.J., Beelen, R., Donkelaar, A. van, Martin, R.V., Millet, D.B., Hoek, G. & Marshall, J.D. (2013). Western European land use regression incorporating satellite- and ground-based measurements of NO_2 and PM_{10}. *Environmental Science & Technology*, *47*(23), 13555-13564. https://doi.org/10.1021/es403089q

World Health Organization [WHO] (2017). *Air pollution*. Retrieved from: https://www.who.int/docs/default-source/thailand/air-pollution/briefing-on-air-pollution-th-thai.pdf?sfvrsn=408572d4_2 [access 02.10.2020].

Summary

Patterns of relationship between PM_{10} from air monitoring quality station and AOT data from MODIS sensor onboard of Terra satellite. Thailand, especially in the northern region, often encounters the problem of having PM_{10} exceeding the normal standard level, which could do harm to people's health. Mostly, such problem is caused by the burning of forest area and open area; this is clearly seen during January–April of every year. Also, the problem as mentioned is caused by the meteorological conditions and the terrains in the northern region that make it easy for PM_{10} to be accumulated. The aim of this study was to analyze the patterns of relationship between PM_{10} measured from the ground monitoring station and AOT data received from MODIS sensor onboard of Terra satellite in Phrae Province located in the northern region of Thailand. The method performed was by analyzing the correlation between PM_{10} data obtained from the ground monitoring station and the AOT data received from the MODIS sensor onboard of Terra satellite during January–April 2018. It was found from the study that the change of the intensity of PM_{10} and AOT in the climate was highly related; it appeared that the correlation coefficient (r) in January–April was 0.92, 0.91, 0.91 and 0.92, respectively. This research pointed out that during February––April, the areas of Phrae Province had the level of PM_{10} that affected health. Besides, from the method in this research, it revealed AOT data received from MODIS sensor onboard of Terra satellite could be applied in order to follow up, monitor, and notify the spatial changes of PM_{10} efficiently.

Authors' address:
Winai Suriya
(https://orcid.org/0000-0003-2214-4294)
Mahasarakham University
Faculty of Science
Department of Physics
Kham Riang, Kantarawichai

Maha Sarakham, 44150
Thailand
e-mail: kroowinai@hotmail.co.th

Poramate Chunpang
(https://orcid.org/0000-0003-1721-1202)
Mahasarakham University
Faculty of Science
Space Technology and Geoinformatics Research Unit
Kham Riang, Kantarawichai
Maha Sarakham, 44150
Thailand
e-mail: poramate_c@hotmail.com

Teerawong Laosuwan – corresponding author
(https://orcid.org/0000-0002-4231-9285)
Mahasarakham University
Faculty of Science
Department of Physics
Space Technology and Geoinformatics Research Unit
Kham Riang, Kantarawichai
Maha Sarakham, 44150
Thailand
e-mail: teerawong@msu.ac.th