EnvironmentAsia
The international journal published by the Thai Society of Higher Education Institutes on Environment

Available online at www.tshe.org/EA
EnvironmentAsia 4(1) (2011) 47-52

PM_{10} Distribution using Remotely Sensed Data and GIS Techniques; Klang Valley, Malaysia

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Abstract

Remote sensing and GIS have been increasingly used for air pollution monitoring in past decade. In this study the distribution of PM_{10} were measured at eight air quality monitoring stations in Klang Valley. The attempt was carried out in GIS environment. The data are belonging to the beginning of the week –Monday- and weekend –Saturday-. Aerosol optical thickness (AOT) values retrieved from Moderate Resolution Imaging Spectroradiometer (MODIS) were interpolated in GIS for comparison with ground station PM_{10} data. The validation between AOT and amount of PM_{10} in the atmosphere were analyzed using non-linear correlation coefficient (NLCC) for 2004. Results showed that the amount of PM_{10} at the beginning of the week is higher than the weekend. Remote sensing data showed better distribution of PM_{10} than ground station data. The NLCC results had a range from (0.10) at Petaling Jaya to (0.61) at Shah Alam. This study shows that GIS is useful tool to generate distribution map of PM_{10}. This study shows that MODIS AOT data are able to present the amount of PM_{10} over large spatial scales that there is no ground stations air quality monitoring.

Keywords: GIS; MODIS; aerosol optical thickness; particulate matter; Klang valley

1. Introduction

Moderate Resolution Imaging Spectroradiometer (MODIS) sensor onboard National Aeronautics and Space Administration (NASA's) Aqua and Terra satellites are able to estimation columnar aerosol from the surface to the top atmosphere that is named aerosol optical thickness (AOT). The significant of this study is to estimate and mapping distribution the PM_{10} in tropical region which may have a different behavior in refining data. Relationship between PM in the atmosphere and satellite-derived AOT has been studied (Chrysoulakis *et al*., 2003; Hutchison *et al*., 2005; Gupta *et al*., 2007). Chrysoulakis *et al*. (2003) showed different location can effect on correlation between MODIS AOT and particulate matter. Hutchison *et al*. (2005) acquired a correlation range from 0.4 to 0.5 between MODIS AOT and particulate matter over Texas and by data averaging over longer time scales; they obtained stronger correlation more than 0.9. Gupta *et al*. (2007) showed a correlation range from 0.11 to 0.48 over Sydney and AOT changes from less than 0.1 to greater than 1.0 in before and during bushfire respectively. Sohrabinia and Khorshiddoust (2007) used satellite data and spatial modeling with the help of GIS to study concentration of different pollutants in Tehran. They used MODIS data and ground station data to monitor and mapping air pollutants. The two main objectives of this paper are: (i) application of MODIS AOT values and ground stations PM_{10} data to monitor and map PM_{10} pollution over Klang Valley. (ii) To determine the correlation coefficient between MODIS AOT and hourly PM_{10} in 2004.

2. Study area and Methodology

Klang Valley is located in center part of west coast Peninsular Malaysia and is delineated by Strait of Malacca to the west and the Titwangsa Mountains to the north and east. There are eight Air Quality Monitoring Stations (AQMS) in Klang Valley (Fig. 1).

In this study, daily AOT from the MODIS (MYD04_L2) onboard Terra satellite and PM_{10} mass concentration were used to mapping distribution of both data and validation between them in 2004. The below methodology flowchart depict, the procedure used to estimate the PM_{10} and create the maps (Fig. 2). The MODIS data have special data format designed for scientific purposes (Folk and Pourmal, 2004). This is a hierarchical data format (HDF) which can include text files, charts, and tables (Sohrabinia and Khorshiddoust, 2007). The files were opened using HDF explorer and the geographical coordinate and AOT values above the land copied to MS Excel. A macro was written to

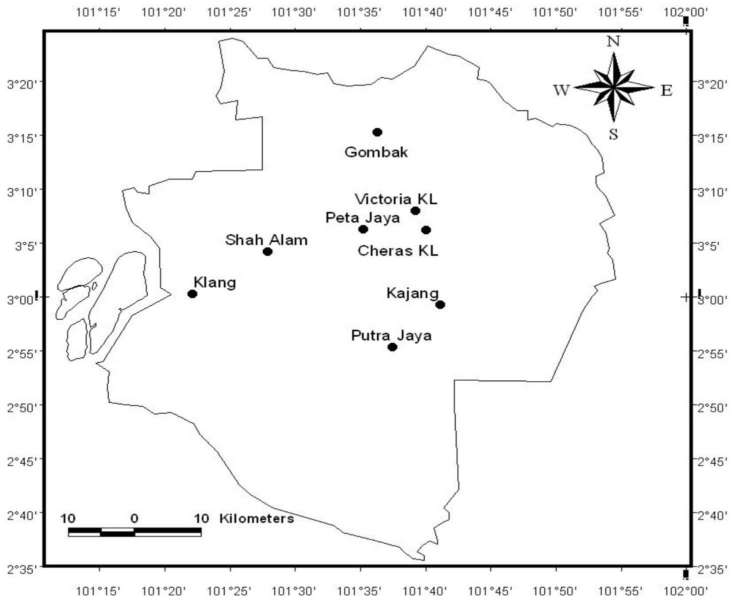

Figure 1. Ground station air quality monitoring in Klang Valley

arrange the pixels of geographical coordinate and pixel of AOT values in columns. In this way the AOT values were extracted for spatial geographic coordinate. For validation analyses between MODIS AOT and amount of PM_{10} in the atmosphere the average of MODIS AOT in 5×5 pixels group (Ichoku *et al*., 2002) was used. Another macro was written for averaging of MODIS AOT in 5×5 pixels group for each station in Klang Valley. For surface GIS mapping, all of the GIS layers were geocoded with the system of decimal degrees, because the MODIS provide a data according to decimal degrees coordinate. Degrees, minutes, and seconds of ground station coordinate converted to the decimal degrees. Both of data and correspond of their coordinate saved with DBF format. Arc View version 3.2 was used for mapping the data. The DBF tables were added in Arc View using 'Event Theme' capability. The geographic coordinate of both MODIS AOT values and ground station converted to point layers in GIS environment.

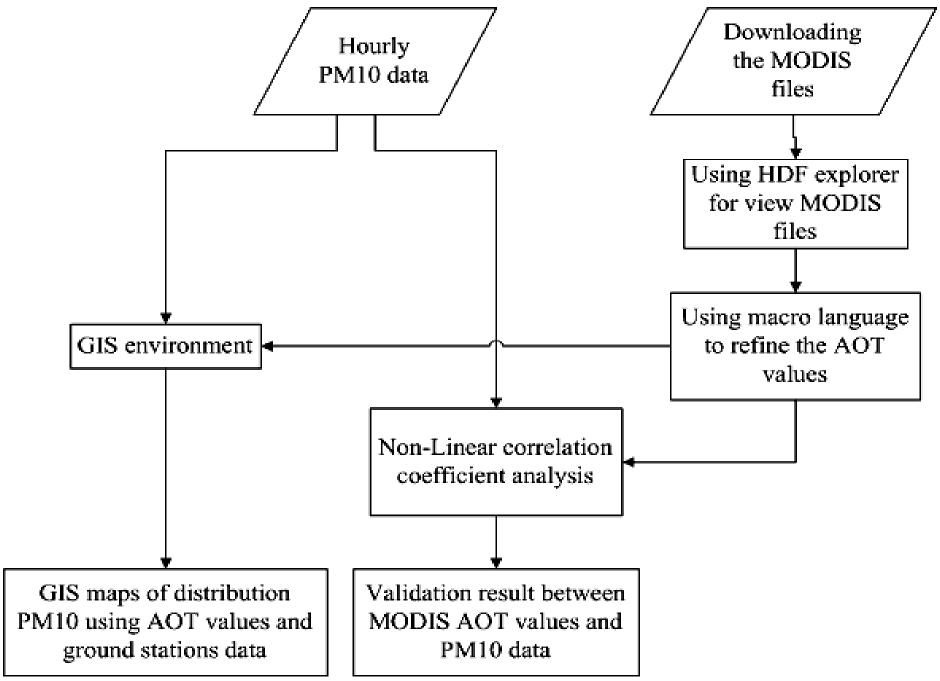

Figure 2. Showing the GIS mapping and validation process

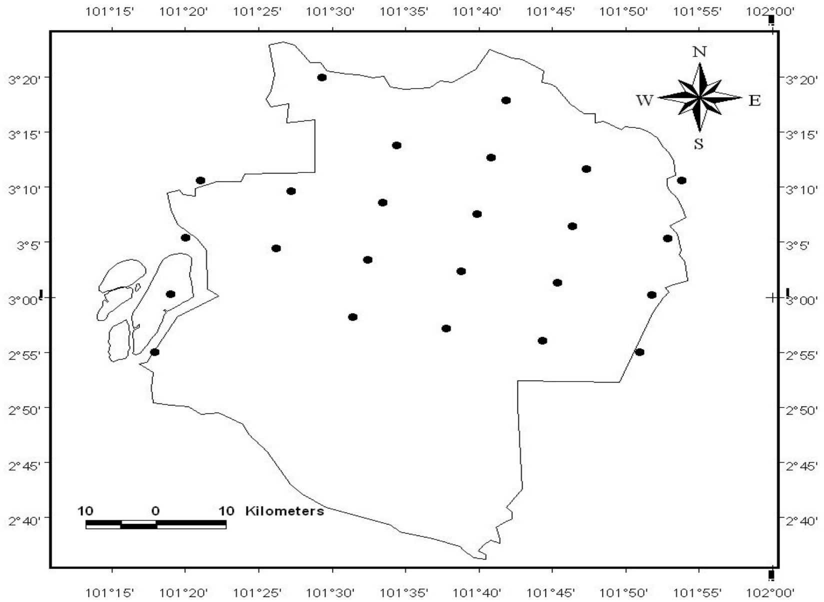

Figure 3. Geographic coordinate of MODIS AOT values in 14 January 2004

3. Results and Discussion

3.1. Surface maps of PM_{10} and AOT values

The integration of remotely sensed data and GIS techniques in conjunction to ground station data could emphasis on the distribution of PM_{10} in a tropical area with map representation. There was a clear different between amount of point distribution in MODIS AOT and ground stations. it is seen that, MODIS retrieval AOT data from two wavelength 0.47 µm and 0.67 over land with 250 and 500 m resolution. AOT product of MODIS in each pixel has a 10×10 km^2 resolution. Therefore, MODIS is able to provide AOT for each 100 km^2. AOT values were not retrieval for south of Klang Valley in 14 January 2004 (Fig. 3). It's may due to cloudy cover. Heavy cloudy cover in the tropical countries like Malaysia is general term. AOT values product processing need to use spatial algorithm like (MOD04) and cloud mask. Each pixel are classified to either confident clear, probably clear, probably cloudy, and cloudy by cloud mask (MOD35) algorithm (King *et al*., 2003).

The results of cloud mask are given to algorithms and may choose to use data to further processing to product AOT data. In the south of Klang Valley the

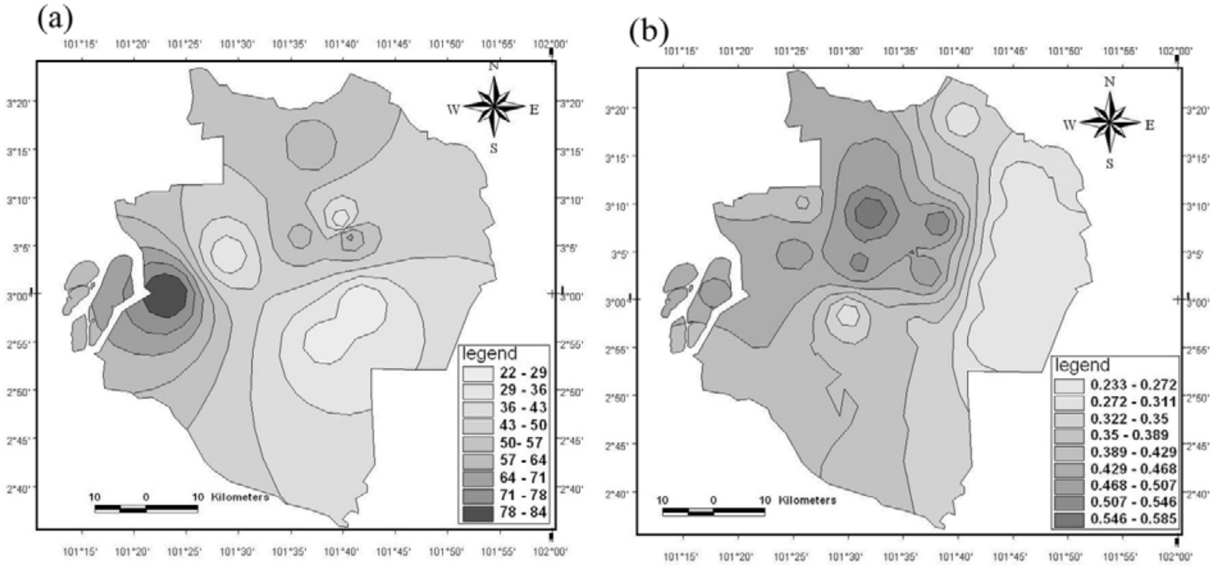

Figure 4. (a) Distribution of PM_{10} based on ground station data in 14 January 2004, (b) distribution of AOT values in 14 January 2004.

MOD04 algorithm may did not run on cloud pixels based on the MOD35 cloud mask in 14 January 2004. Surface maps of AOT values and PM_{10} mass were showed in Fig. 4. Maps were made based on MODIS and ground station point. Fig. 4(a) shows a real amount of PM_{10} at ground, but this data just is reliable for a few meters around the ground stations. On the other hand for creditable of MODIS AOT should to analyzes of the validation between

AOT data and PM_{10} mass concentration at ground station. Surface map of MODIS AOT shows better distribution of PM10 than ground station surface map.

AOT surface map created based on 23 AOT values (Fig. 2), but for ground station surface map, 8 PM_{10} data were used. PM_{10} pollution recorded by ground station on a beginning of the week –Monday- and weekend -Saturday- were interpolated also in GIS environment to produce surface maps (Fig. 5).

Clearly the different was obtained between the amount of PM_{10} at the beginning of the week and on weekend. Increase and decrease of PM_{10} in during the week is because of the human activity. The level of particulate matters is mostly influenced by motor vehicles and industry during normal period (without haze) (Afroze *et al*., 2003).

3.2. Validation between MODIS AOT and PM_{10} mass concentration

The non-linear correlation coefficient (NLCC) was used to show any correlation between MODIS AOT and hourly PM_{10} mass in eight AQMS in Klang Valley in 2004 (Table 2). The lowest and highest NLCC were obtained at Petaling Jaya 0.1 and Shah Alam 0.62 respectively. The *p*-value reports in column 3 and indicates the probability; whether the same result will obtain if the correlation between the data sets are zero. The *p*-value higher than 0.05 means that cannot use the linear correlation coefficient because coefficient is not truly different from zero. Number of points (column 2) represents the sample size used for successive correlation tests which are lower than 50 for each station. Low amount of points may be due to algorithms and cloud mask which NASA used for retrieval data over tropical area like Malaysia. The cloud mask using 48 bits of output provide individual cloud test result and each cloud detection test has a value from one (high confidence clear) to zero (low confidence clear) (King *et al*., 2003). Finally a minimum confidence is determined for each group. Algorithms are given the result and different algorithms show different sensitivities to cloud mask result (King *et al*., 2003). The mean of PM_{10} at Klang, Victoria K.L, and Cheras K.L were acquired higher than other stations (Table 2). Result of Figs. 5(a-b) and Figs. 4(a-b) is agreement with this result.

It is due to human activity. Victoria K.L and Cheras K.L places have a more population and Klang is a seaport, subsequently human activities are higher than other area. The AOT values were obtained higher at Petaling Jaya for 14 January 2004 [Fig. 4(b)] than other stations, on the other hand the NLCC between AOT values and PM_{10} mass was acquired lower for this location as compared to another station. Major

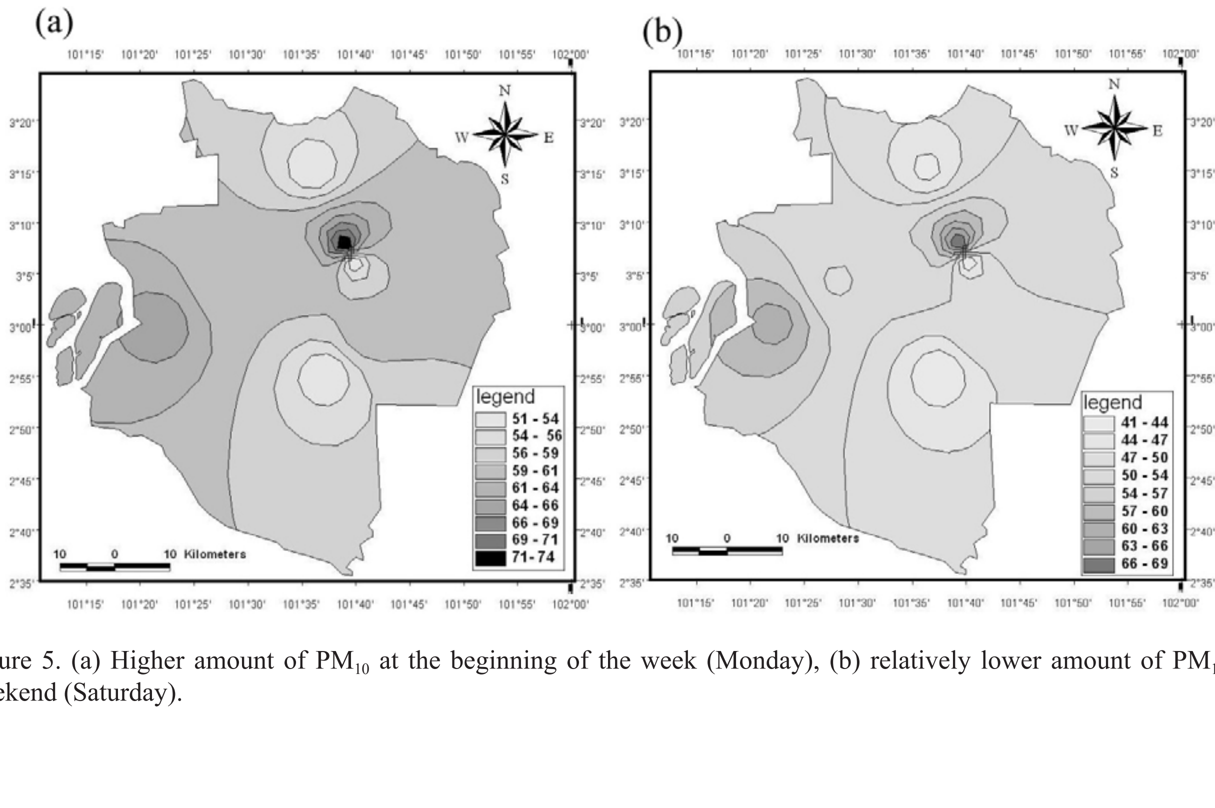

Figure 5. (a) Higher amount of PM_{10} at the beginning of the week (Monday), (b) relatively lower amount of PM_{10} on weekend (Saturday).

Table 2. Correlation statistics between MODIS AOT and PM_{10} for eight AQMS in Klang Valley in 2004

Stations name	No. Points	*p*-value	Corr. coeff	PM_{10} ($\mu g/m^3$)		MODIS AOT (0.55μm)	
				Mean	SD	Mean	SD
Gombak	48	0.80	0.36	54.39	27.26	0.44	0.37
Klang	15	0.67	0.24	69.20	16.51	0.56	0.48
Victoria K.L	27	0.44	0.29	59.14	37.12	0.40	0.37
Petaling Jaya	30	0.34	0.10	46.46	15.08	0.45	0.37
Kajang	25	0.37	0.21	42.80	21.83	0.47	0.37
Shah Alam	23	0.08	0.62	55.37	17.85	0.51	0.45
Putra Jaya	15	0.48	0.54	48.20	16.44	0.54	0.39
Cheras K.L	21	0.33	0.33	65.33	19.48	0.50	0.41

industrial units of Klang Valley are in Petaling Jaya in comparison with the other sites, and industrial activity cause to create sulfur dioxide (SO_2). SO_2 emissions in the atmosphere can be transformed to sulfate (Quan *et al*., 2008). Generally sulfate particle has higher light extinction efficiency than other particles especially under humidity conditions (Chin *et al*., 2002). Therefore, AOT will retrieval different than the real range, and the NLCC decreases. Scatter plot of MODIS AOT versus amount of PM_{10} at ground station were showed for Shah Alam and Putra Jaya in figure 6. In most of case amount of MODIS AOT were obtained from 0.1 to 0.8. Correlation coefficient between AOT and PM_{10} mass in the high amounts of PM10 is better than low amounts. For example, increases PM_{10} mass more than 80µg/m^3 in Putra Jaya the AOT increases too. This range in Shah Alam is more creditable than lower PM_{10} in 70μg/m^3.

Result of Fig. 6 showed that atmospheric boundary layer (ABL) has major effect on correlations between MODIS AOT and PM10 mass. Xu *et al*. (2003) and Zhou *et al*. (2005) showed the most important reason for the change in air quality is the change in ABL. When ABL is low, aerosols are trapped in the lower atmosphere and columnar AOT are representative of PM_{10} measurements at ground, result correlation increases.

Lowest correlation between MODIS AOT and PM_{10} mass was showed in figure 7. Amounts of PM_{10} are lower than 80μg/m^3 that is due to low human activity or high level of ABL. When the ABL is high the aerosol distributed in the atmosphere so that the accuracy of surface measurement is minimized, results correlation decreases.

4. Conclusions

MODIS AOT data and PM_{10} mass concentration measured by eight AQMS in Klang Valley were used in 2004. GIS environment was used for mapping of surface distribution both PM_{10} mass and AOT values retrieval

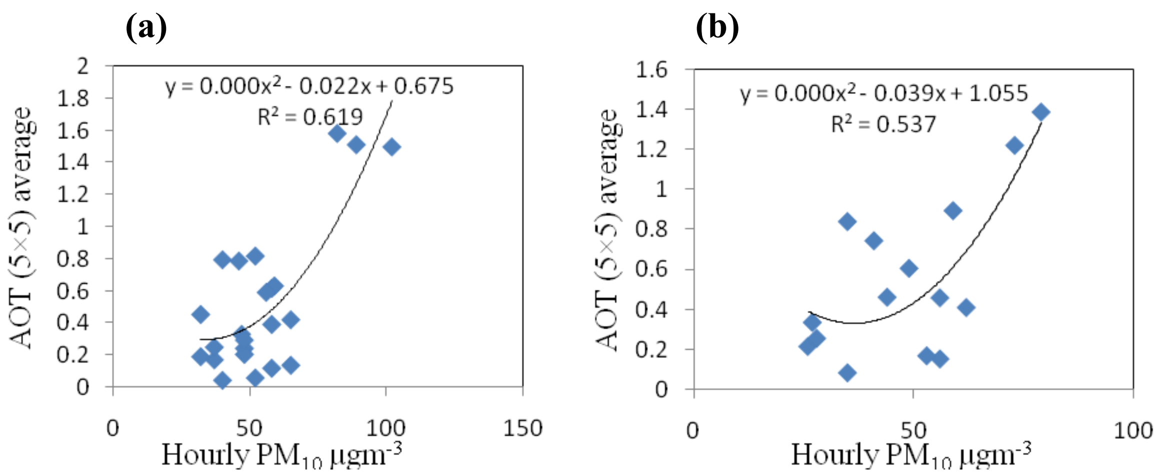

Figure 6. (a) and (b) scatter plot of non-linear correlation coefficient for Shah Alam and Putra Jaya respectively.

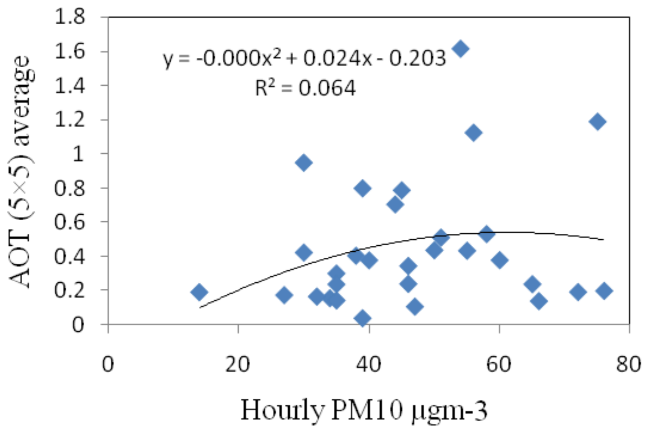

Figure 7. Scatter plot of low amount of PM_{10} versus MODIS AOT in non-linear correlation coefficient at Petaling Jaya

from MODIS sensor. GIS environment were also used to shows an amounts and distribution of PM_{10} in busy day-Monday- and week holiday –Saturday- over Klang Valley. Non-linear correlation coefficient was used to shows the validation between MODIS AOT and PM_{10} mass. Amount of AOT points were obtained more than PM_{10} stations. Due to cloudy cover amount of sample size which used for correlation tests were obtained lower than 50 for each station. It can be concluded MOD35 cloud mask is not powerful for retrieval data over tropical area. The surface map of AOT showed better distribution of PM_{10} than the surface map of ground station data. Surface map of PM_{10} in busy day shows high level of PM_{10} than holiday. Validation analysis between MODIS AOT and PM_{10} mass showed that ABL and composition of particulate are able to decrease or increase the result. If ABL is low the correlation was acquired high and vice versa. Satellite and GIS are able to show the distribution of PM_{10} over large scale that are not possible by ground stations alone.

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Received 23 September 2010
Accepted 2 November 2010

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