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SATELLITE DATA SUPPORTING TO MONITOR AIR QUALITY FROM PM2.5 INDICATOR

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ABSTRACT

The paper presents the research to simulate air quality from $PM_{2.5}$ indicator determined by satellite data. The relationship between ground-based station data and Aerosol Optical Depth (AOD) imagery from Moderate Resolution Imaging Spectroradiometer (MODIS) was examined to establish a regression equation for mapping $PM_{2.5}$ distribution in Ho Chi Minh city (HCMC). This equation was used for simulate the $PM_{2.5}$ distribution in the dry season of 2018. The research showed that the highest concentration of $PM_{2.5}$ was in February, mean value was higher than QCVN 05:2013 (32.5 μg/m^3 compared with 25 μg/m^3, average in a year. This results is very helpful supporting to detect and monitor the air quality for HCMC.

Keywords: Air Pollution, AOD, $PM_{2.5}$, MODIS, regression.

1. INTRODUCTION

$PM_{2.5}$ or also known as fine particle which has aerodynamic diameter ≤ 2.5μm is generated by both human-made and natural sources, but the majority is from human-made (vehicle engine, power generation, urban heat, etc) [1]. According to WHO, exposure of fine particle in high concentration and long term can worsen lung and heart condition, increase the ability of hospital admissions or may be deaths, especially children, elderly and member of sensitive groups [2]. According to the report of Green ID (2018), in the first trimester of 2018, the number of hours which AQI in HCMC is classified at Unhealthy level occupied 28.3% in total, much higher than the same period of 2016 and 2017 (0.6% and 9.6%, respectively) [3].

In Ho Chi Minh City, installation of $PM_{2.5}$ ground-based stations at some key areas only restricts the ability in assessing the time-space dynamics of fine particle. Therefore, based on real-time $PM_{2.5}$ data at available stations, remote sensing technique is promising applied to compute and estimate the $PM_{2.5}$ concentration for the whole city. Currently, there are 2 common methods being used by researchers to establish map of polluted substances. First approach is regression models [4], [5]. Researchers investigated the relationship between pollutant concentration, atmospheric index, hydrological parameters and so on to build the regression model. One of the most common atmospheric index being used by researchers in studies of particle matter is Aerosol Optical Depth. AOD is a measure of beam solar attenuation due to the obstruction from dust or haze. It is a dimensionless number and determined by amount of aerosol in an atmospheric vertical column from the ground surface to the top of the atmosphere at given wavelengths [6]. From an observer on the ground, an AOD of less than 0.1 is clean, characteristic of clear blue sky, bright sun and maximum of visibility. As AOD increases to 0.5, 1.0, and greater than 3.0, aerosols become so dense that sun is obscured [7]. Beside regression methods, some scientists have utilized simulation models to detect the variation tendency of $PM_{2.5}$/AOD ratio for research areas, then verify by surfaced-measured $PM_{2.5}$ data [8], [9]. Each method has own advantages and disadvantages, but they both relatively simulate pollutant dispersion in research areas. In this research, regression model is used to estimate for the whole HCMC from MODIS-AOD satellite imagery.

2. DATA AND METHOD

2.1. Data

Ground-based $PM_{2.5}$ concentration: $PM_{2.5}$ data was extracted from a monitoring station located at US Consulate (Coordinates: 10°46'59.9N, 106°42'03.2E) and another station was invested by Environmental Source Samplers company (Coordinates: 10°48'54.5 N, 106°43'11.0 E) at the time that MODIS Satellite passes over the research area for data synchronization (10:00AM - 11:00AM for Terra, 2:00PM - 3:00PM for Aqua, respectively). Furthermore, MODIS image quality is much depended on weather and cloud coverage, so $PM_{2.5}$ data were collected in clear sky days of dry season from January to April (2016 - 2019).

MODIS Imagery based-AOD: AOD retrieved from MODIS imagery which has been computed by NASA is 3 km-spatial resolution and stored online for free download. Actually, scattering and absorption of both molecular and aerosols in atmosphere was only important and occurs in visible regions [10]. Therefore, this research focused on measuring and assessing at 3 wavelengths 0.47 µm, 0.55 µm, 0.66 µm.

2.2. Method

The main research method is correlation analysis, a statistical technique that used to measure how strongly a pair of 2 variables which were $PM_{2.5}$ data and MODIS-AOD are related to each others. To enhance the accuracy and reliability, 55 AOD values at three aforementioned wavelengths and corresponding $PM_{2.5}$ data during the period time of 2016 - 2019 were derived to establish the regression function in order to build the map of $PM_{2.5}$ across Ho Chi Minh City.

Pearson correlation analysis is the first step in building regression model. Pearson correlation coefficient (R) is a measure of the strength of the association between two quantiative, continuous variables. If Pearson analysis shows 2 variables are correlated to each others, establishment of regression model will be conducted afterward. In this step, to increase the realibility and accuracy, beside the linearity, other curve estimation regression models were also run. Assessment criteria includes correlation coefficient (R^2), Sig Annova and Sig Coefficient are also need to be considered (these 2 values must be less than 5%). To verify the feasibility of regression model, error calculation was used to compare the deviation between MODIS image-based $PM_{2.5}$ concentration and the ground $PM_{2.5}$ data (formula 1).

$$E = \sqrt{\frac{1}{n}\sum(P_{cal} - P_{meas})^2} \quad (1)$$

Where, P_{cal} was $PM_{2.5}$ from regression model, P_{meas} was the ground $PM_{2.5}$ data.

3. RESULTS AND DISCUSSION

First of all, through Pearson correlation analysis, $PM_{2.5}$ concentration and AOD of green light (0.55µm) indicated the most significant correlation at the 0.01 level (2-tailed) among 3 wavelengths of visible light spectrum (R^2 = 0.900), while blue and red lights showed lower correlation level (0.870 and 0.886, respectively). After Pearson correlation, regression analysis result showed the most appropriate regression model was in form of linearity. The statistical analysis also indicated the best correlation with $PM_{2.5}$ is the AOD of wavelength 0.55µm (in green visible spectra), R^2 = 0.810 (Figure 1). At other side, the result of error evaluation (E) computation was 5.93 µg/m^3, demonstrating that the difference between simulated $PM_{2.5}$ and ground data from monitoring station was not really significant. Therefore, the regression model of MODIS-AOD (0.55µm) has been selected to simulate $PM_{2.5}$ for the entire of research area (formula 2).

$$PM_{2.5} = 36.684 \times AOD + 6.839 \quad (2)$$

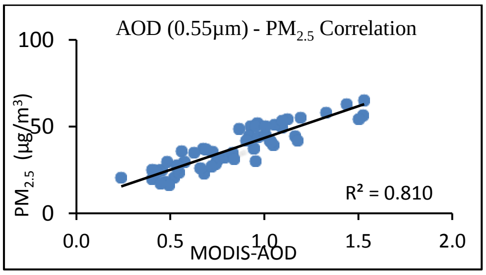

Figure 1. Regression model of linearity between MODIS-AOD and $PM_{2.5}$ at wavelength 0.55µm.

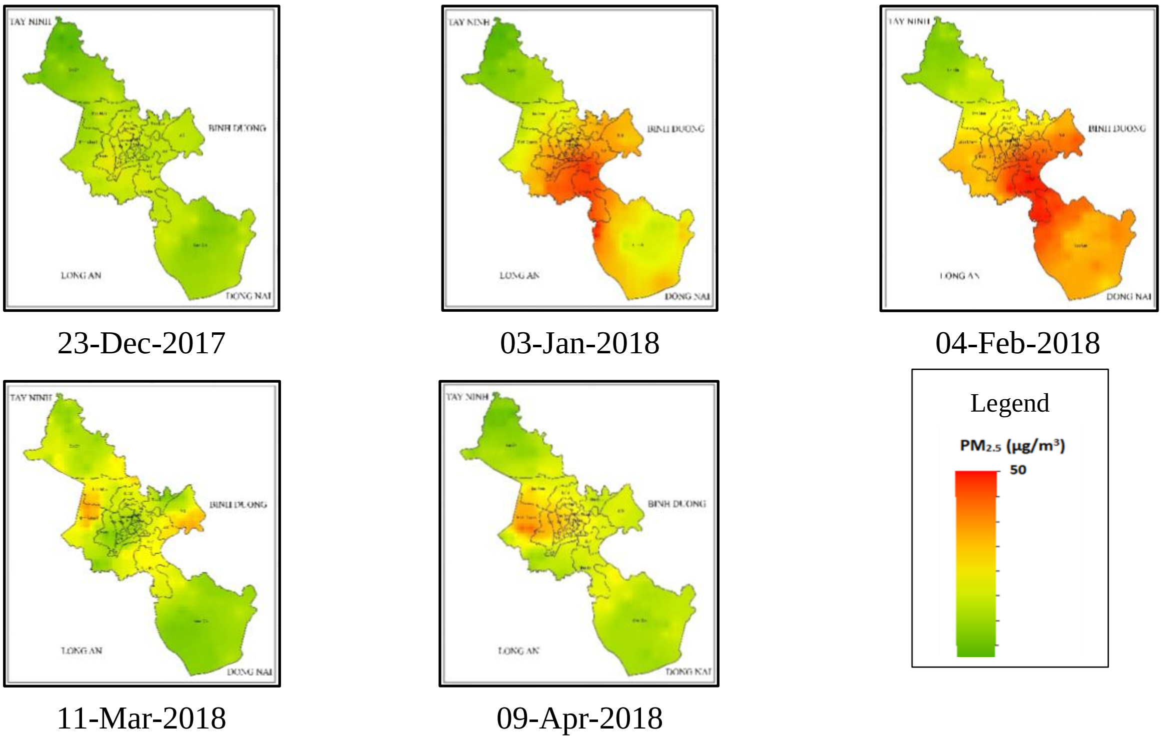

Figure 2. Map of $PM_{2.5}$ distribution over Ho Chi Minh City.

The Map of $PM_{2.5}$ distribution in HCMC was established on MODIS satellite image at 10:00 am, on representative days of each month in dry season (table 1). This time can be considered as one of the largest dust generation time in a day. The map of figure 2 showed that the $PM_{2.5}$ concentration was higher at existing central districts, such as Dist. 1, 3, 5, Tan Binh, Phu Nhuan, Go Vap, etc. This can be explained by the intensity of transportation on main roads and infrastructure density in each particular section was tremendous, especially at rush hours. In contrast, suburban territories/districts, such as Cu Chi, Binh Chanh and Can Gio, where have small traffic density, the $PM_{2.5}$ tended to be lower. Especially, in Can Gio district, the development of mangrove forest is an advantage in prevention of invading of $PM_{2.5}$ from other areas.

On 23-Dec-2017, since this is the transition time between rainy and dry season, the average $PM_{2.5}$ on the entire HCMC was low (19.9 µg/m^3). However, $PM_{2.5}$ concentration gradually increased by next months, and the most severe time of dry season was in February which $PM_{2.5}$ mean was 32.5 µg/m^3, higher than threshold that specified in National Technical Regulation on Ambient Air Quality, QCVN 05:2013 (25 µg/m^3, average in a year). In February, almost the south of HCMC was ranked as serious pollution area. The $PM_{2.5}$ at some places came up to 49.7 µg/m^3 (table 1). Although, these are only the representative days for each month in dry season, it showed that inside HCMC, there are still areas that $PM_{2.5}$ concentration exceeded Vietnam Standard every month (figure 2). With rapid development of industry and economy, this will be a serious warning for air quality in Ho Chi Minh City.

Table 1: Statistics of $PM_{2.5}$ concentration by representative days (µg/m^3)

Dates	Mean	Max	Min
23-Dec-2017	19.9	28.9	10.34
03-Jan-2018	26.6	44.1	11.6
04-Feb-2018	32.5	49.7	16.6
11-Mar-2018	25.2	37.8	16.5
09-Apr-2018	24.1	41.7	14.1

4. CONCLUSION

This research has an initial success in verifying the assumption of association between $PM_{2.5}$ concentration and Aerosol Optical Depth AOD. According to the correlation analysis result, $PM_{2.5}$ showed the best correlation with AOD at the green wavelength (0.55µm) in form of linearity (R^2=0.810). The research showed that the highest concentration of $PM_{2.5}$ was in February, mean value was higher than QCVN 05:2013 (32.5 µg/m^3 compared with 25 µg/m^3, average in a year). At scientific side, this research will be a basis for further studies which appling remote sensing in air quality monitoring. For society, this research will help environmental managers as a reference source in issuing policies in order to mitigate and prevent $PM_{2.5}$ emission in Ho Chi Minh City.

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