PM2.5 VARIATION ESTIMATED FROM MODIS AEROSOL DATA: A CASE STUDY OF THE NORTH OF VIETNAM

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Abstract

PM2.5 refers to particulate matter (PM) with a diameter of smaller than 2.5 micrometers flying in the atmosphere. The high concentration of PM2.5 seriously affects the health of people and animals. Using Aerosol Optical Depth (AOD) index achieved from satellite images is possible to estimate and monitor the variation of PM2.5. This study observes the variation of AOD and the maximum PM2.5 concentration over three sub-regions in northern Vietnam based on the daily MODIS aerosol product and PM2.5 measured at a ground station. The experiment shows that the critical PM2.5 pollution is in the Red river delta during April due to the highly industrial cities, dense traffic transportation, and residue burning after agricultural harvesting. This study is an example of the capacities of using satellite data to monitor air pollution and it opens future studies on assessing the long-term trade-off between social, economic development and environment.

Keywords: *Aerosol optical depth, PM 2.5, air pollution.*

I. Introduction

Satellite remote sensing using to measure trace gases and aerosol properties which is related to air quality has been developing rapidly. Three unique properties of air qualities based on satellite data are global coverage, observing in a large area at a time, progressing spatial resolution [1]. Based on the relationship between AOD and PM, lots of empirical models to invert PM from AOD have been popularly applied over different areas [2-4]. In Vietnam, several studies of air quality monitoring were implemented using high and medium resolution satellite images such as Spot images [5], Landsat images [6, 7], MODIS images [8]. However, these studies mostly focused on estimating PM10 for a specific area in Ha Noi or Ho Chi Minh city. As an exception, Nguyễn et al., (2014) developed a monitoring system of PM for whole the Vietnamese territory with the high resolution for Ha Noi cities and medium resolution for the rest [8]. The variation of PM 2.5 concentration was not satisfactorily analyzed.

This study investigates the monthly variation of AOD and estimates the PM2.5 concentration based on the combination of AOD estimated from MODIS image and PM2.5 measured at a ground station. Taking a case study of northern Vietnam, this experiment monitors the monthly variation of PM2.5 according to three sub-regions North East (NE), North West (NW), and Red river delta (RRD) which have the discrete natural environment and economic development as well. We express heartfelt thanks to valuable supports from the LOTUS LMI project giving us a chance to present results of the study in the CARRES conference.

II. Study area, Data, and Methodology

Northern Vietnam is characterized by subtropical weather with a heavily monsoon-influenced. The NE region of the study area is specified by the mountainous topography with the concentration of heavy industry as coal exploitation. The NW region is characterized by pure agriculture in a very high mountainous area. In contrast, RRD is the flat coastal area with the condense industrial zones, traffic transportation, and rapidly build-up expansion. The diversity of the topography, climate characteristics, and social, economic development causes the difference of AOD as well as PM2.5

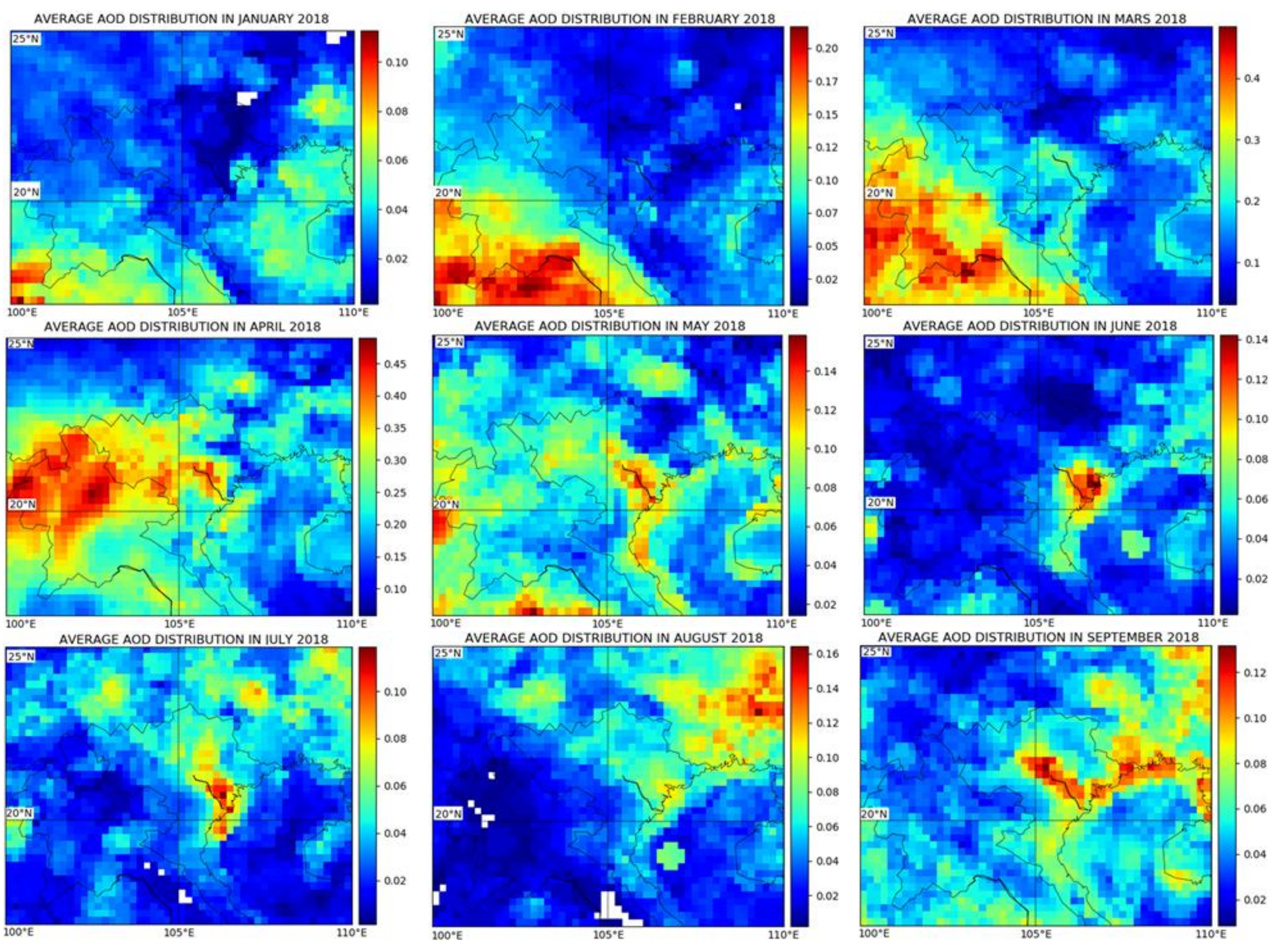
concentration between regions. This study investigates the AOD distribution in the frame from 17ºN to 25ºN, from 100ºE to 110ºE, which covers the Northern part of Vietnam and the surrounding areas.

The major data using in this study is MODIS Aerosol (MOD04_L2) product level 2. This product provides daily data at the spatial resolution of 10 km. The spatial resolution is fine, but a geo-correction process is required. The data acquired during the years 2016, 2017 and 2018 are manually collected for analysis. In addition, ground measurement data of PM2.5 at the U.S Embassy in Hanoi are collected corresponding to 3 years of AOD data.

The monthly average and extreme values are then calculated for every pixel, which helps to map the spatial distribution of average and extreme values of AOD of one month. A linear regression model is built to estimate PM2.5 concentration from AOD values, and then in-situ PM2.5 in 2016 is compared to the PM2.5 data derived from AOD to assess the accuracy of the regression model.

III. Results and Discussions

Figure 1 represents the monthly average of AOD estimated from MODIS data in 2018. The color ramp at each month associates with the variation of AOD value in each individual map. The highest values of AOD with around 0.45 can be seen in March and April concentrating in Lao and the Red river delta. Contrarily, the lowest AOD with only below 0.04 is in January. The AOD value remains at very low in the mountainous areas during the year in the North of the study area where is the location of the Hoang Lien Son range so-called the roof of Indochina. The variation of AOD during the year also represents the variation of PM2.5 concentration.



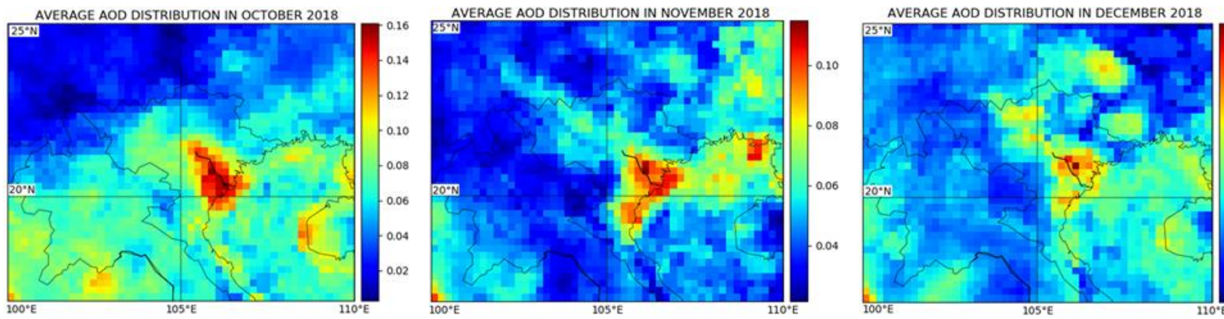


Figure 1. The monthly variation of the average of AOD estimated from MODIS data in 2018

A series of 48 data points composing of PM2.5 ground measurement and AOD acquired at the same time are used to build the linear model to convert PM2.5 from AOD (Figure 2). The correlation between PM2.5 and AOD is good in the AOD range from 0.04 to 0.7, then it gradually reduces according to the increase of AOD. Overall, the correlation between the two series is acceptable with 0.6 of R^2, the corresponding linear equation (Figure 2) is used for further analysis. The accuracy of PM2.5 estimated from this model is ±49 $\mu g/m^3$ as we use 18 data points of in-situ PM2.5 acquired in 2016 for accuracy assessment.

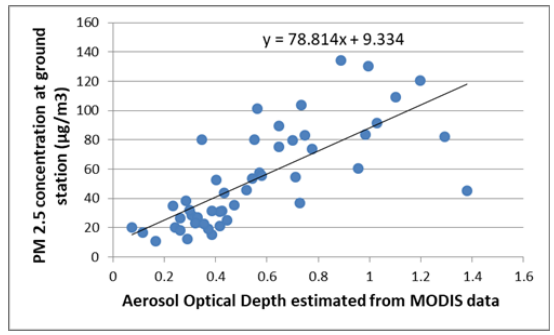


Figure 2. The linear model to invert PM2.5 from AOD data

Figure 3A represents the maximum concentration of PM2.5 according to the 3 sub-regions of the study area. It is obviously seen that the RRD area surfers critical pollution with the highest PM2.5 concentration over the year. The PM2.5 in RRD is even double greater than that in NW through 6 months from June to December. The PM2.5 concentration in the NE area is relatively higher than that in the NW area during the year excepting March. In general, the maximum concentration of PM2.5 is at the peak of approximate 300 $\mu g/m^3$ in April, triple greater than the one in other months. The critical change of PM2.5 in April may refer to the residue burning after agricultural harvesting [9]. Figure 3B shows the influence levels of PM2.5 concentration on health according to the Environmental Protection Agency (EPA) standard in April 2018 with the hazardous level covering RRD and almost the NE area.

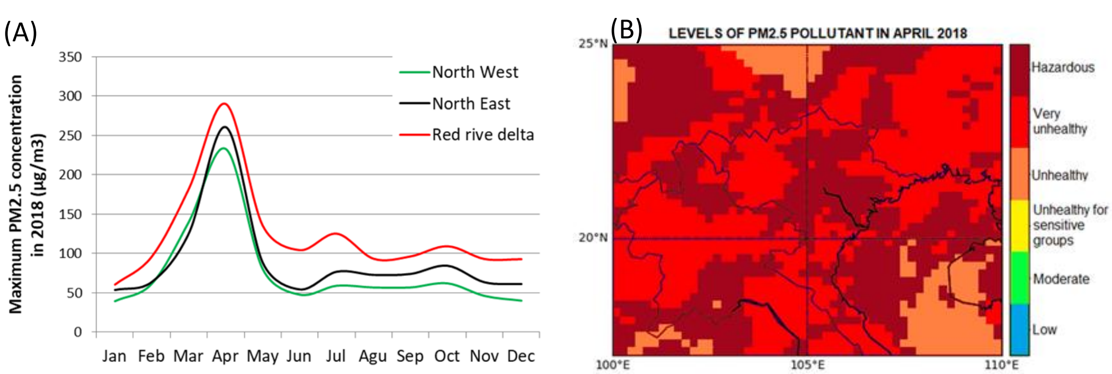


Figure 3. (A) Maximum PM2.5 according to 3 sub-regions in 2018, (B) Map of health influence level at maximum PM2.5 during April 2018

It is a reality that the interpretation of air qualities from satellite data is often less straightforward as compared to in-situ measurements [1]. However, the approach in this study is still the most effective approach in the field of air quality monitoring. The PM2.5 estimation from AOD is not only affected by the accuracy of AOD based on MODIS data but also by the local atmospheric conditions. This study emphasizes the method to initially estimate PM2.5 by integrating multi-temporal AOD and in-situ PM2.5, but the effect of meteorological conditions on the accuracy of estimating PM2.5 may be mentioned in the future study.

The tropical monsoon climate coincides with the extensive cloud cover which limits the number of achieved MODIS data and the frequency of AOD data as well. Though, the trend of PM2.5 well correlates the natural, social, and economic condition of the study area. The RRD area is the most PM2.5 pollution due to the highest economic development with the explosion of traffic transportation and build-up constructions. In contrast, the NW region is the cleanest area because of the pure agriculture economy in a mountainous area.

IV. Conclusions

This study exploits the ability to use AOD based on satellite data to estimate particulate matter in the atmosphere. The results represent the monthly variation of AOD and the pollution levels of PM2.5 over three sub-regions of northern Vietnam. In addition, the study opens future studies related to evaluating the trade-off between economic, social development and air pollution which is the critical issue in Vietnam and global scale as well.

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