

Manipulating API and AOD data to distinguish transportation of aerosol at high altitude in Penang, Malaysia

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Abstract. Air pollution index (API) is an index commonly used in Malaysia to determine the air quality level. It is a ground truth data measurement which is unable to unambiguously quantify air quality level at higher atmosphere. On the other hand, aerosol optical depth (AOD) from AERONET data obtained using sun photometer provides reading of the air quality for a column of atmosphere from ground surface. We first determine the quantitative correlation between the API and AOD data collected in Penang, Malaysia, between January – September, 2012, using two independent methods, one based on regression analysis and the other interpolation. Our purpose is to establish a systematic numerical procedure to determine whether aerosol transported in high altitude from other location has occurred. Two independent methods for establishing the quantitative relationship between the API and AOD data were used as a way to facilitate the verification of our approach. In our method, data from southwest monsoon period (August to September) were used as “calibration dataset” to establish the quantitative correlation between the AOD and API data. The established calibrated coefficients is then used to predict the AOD of other months, which are then compared against the data actually measured. Discrepancy between the predicted and measured AOD data can then be interpreted as an indication of whether the atmosphere at high altitude is polluted by aerosol transported from other location. If the predicted AOD is much larger than that measured, back trajectory analysis was applied to identify the aerosol transported source. This procedure is very helpful to investigate the aerosol transportation and distribution patterns during monsoon and non monsoon periods.

1. Introduction

Scientific community have done a lot of studies to investigate the impact of natural and anthropogenic sources of air pollution on weather and climate systems. One of the interested parameters is aerosol optical depth as aerosol may influence Earth radiation forcing [1, 2] and changing cloud properties and lifetimes [3, 4]. Recently, the concerned topic was on Asian monsoon circulation especially during August and September of 2012, as satellite observations showed a strong impact of the southwest monsoon on tropopause transition layer composition and has a direct relationship to surface sources including pollution and biomass burning.

There were many studies indicated that the aerosol may be transported to other far location from origin place [5-7] and sometimes even can reach the upper troposphere/lower stratosphere (UT/LS) due to convection [8-11]. The aerosol sources mainly come from biomass burning as this activity usually involving wide region of forest fire caused by both naturally and human made. Large amount of aerosol emitted during burning processed, and they were transported by advection and convection activity in the atmosphere especially during monsoon season.

In this paper, we present techniques to predict AOD readings by using two independent approaches which involved numerical procedures using ground measured data of API in year of 2012. From the

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predicted AOD result, we compared the result of measured and predicted AOD to estimate whether the aerosol distribution level belonged to low or high level in the atmospheric column.

2. Data and methodology

Columnar aerosol properties as AOD (level 2.0) at wavelength 500 nm from <http://aeronet.gsfc.nasa.gov/> and API data from <http://www.doe.gov.my/apims/index.php> were downloaded during the period of southwest monsoon (August and September 2012). Level 2.0 AOD data was used in this study because they had been cloud-screened and data assured [12]. The details of the AERONET such as measurement concept, instrument precision, instrument calibration, data accuracy, data transmission, processing system, data processing and archival browser was discussed by [13]. On the other hands, API is mainly used to determine the air pollution level in Malaysia in term of sulphur dioxide (SO₂), nitrogen dioxide (NO₂), carbon monoxide (CO), ozone (O₃), and suspended particulate matters of less than ten microns in size (PM 10) which computed by using US-EPA technique base on these five pollutants [14]. Both of these data source are from site of Universiti Sains Malaysia (USM), Penang (refer to the five-edge star in Fig. 1) where USM is located in a high population region.

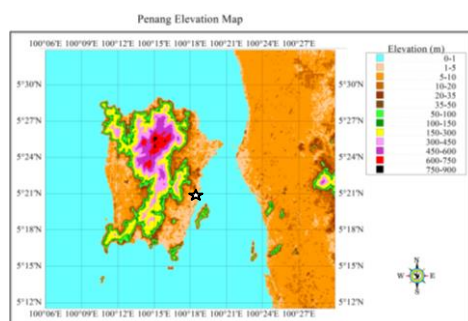


Figure 1. The topography map produced from global digital elevation model (GDEM) is showing the high mountain and low plain region in Penang. Five edge star is the site of Universiti Sains Malaysia, Penang.

Initially, 2 different data sources such as AOD and API were obtained from southwest monsoon period (August to September, 2012) in Penang, Malaysia. These 2 different sources have different acquiring time interval, therefore dataset was selected for about 30 minutes different between them. Therefore, all dataset was converted to Julian day in order to pick the dataset which coincided within 30 minutes between them by MATLAB programming (total 75 data points was selected within these months). We predict the AOD using two different methods: (1) regression equation, and (2) interpolation method.

Regression analysis was then used to determine the correlation between AOD and API. This regression model was then applied to calculate for other months to investigate the aerosol distribution. About the interpolation method, the upper limits (the largest values of data point) and the lower limits (the smallest data point) in a plot of measured AOD versus API was joined with line to form a band. This band will be used to predict the AOD in future. And we can easily give the error bar of the predicted AOD value as the predicted value will be located within the band created but this technique only valid with this band. After that, new data set for other months will be predicted base on this technique. In the interpolation method, we connect two adjacent data points by a straight line. The value of AOD between the two data points can be calculated using interpolation. Using this method, we can 'predict' the AOD value for any API. We then compare the predicted AOD from both methods. From the comparison, we identify the better method and use it to identify the aerosol distribution trend.

3. Results and discussions

From Fig. 2, the API and AOD shows a similar trend as a function of time. This means that API is proportional to AOD. Additionally, the regression analysis showed strong correlation of API with AOD because the R^2 was as high as 0.8331 (refer to Fig. 3). From the data point in Fig. 3, we observed that when API values at about 52 to 59 and 75 were highly deviated in this study. However, mostly the data point was well correlated in this regression analysis, therefore this high correlation of the API to AOD model was used for predicting the AOD in other months. When predicted and

measured AOD versus API was plotted for investigation of their accuracy of the model (refer to Fig. 4), some of the predicted AOD values were well matched with the measured AOD but some of them were over- and under-predicted due as shown by the deviations of data points.

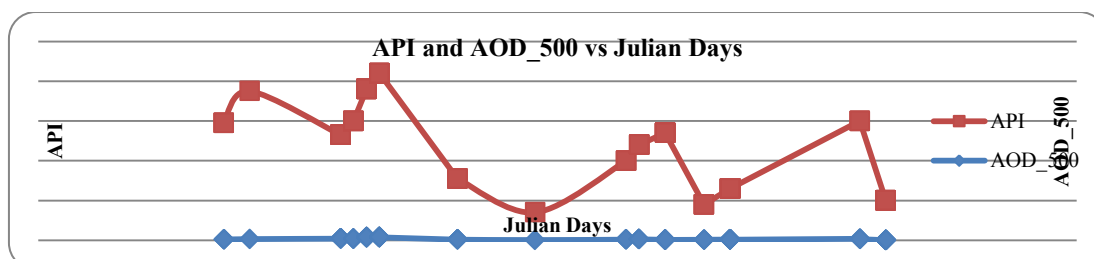


Figure 2. API and AOD_500 was plotted versus Julian days during Aug and Sep 2012.

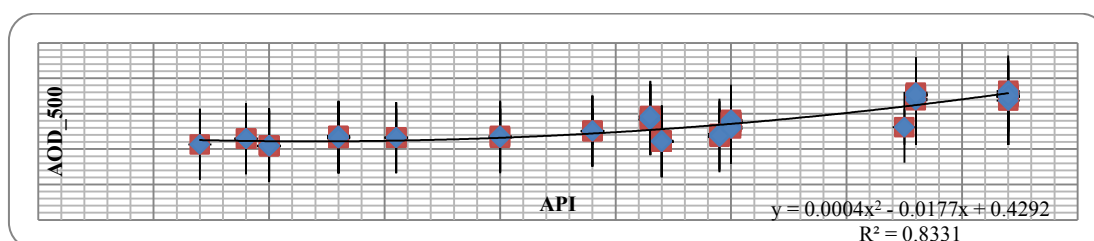


Figure 3. AOD_500 versus API was plotted for 50 days data during Aug and Sep 2012.

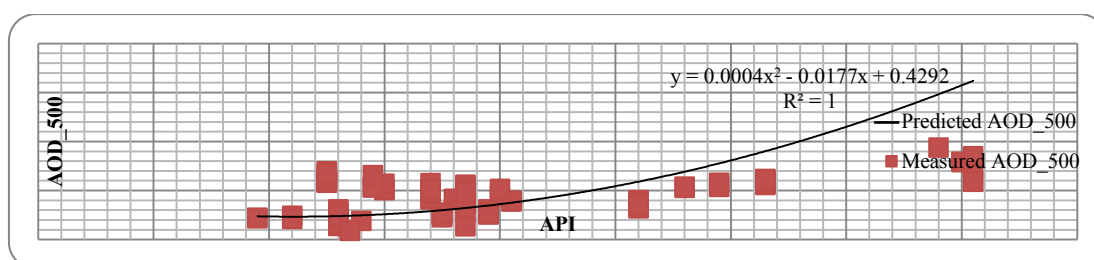


Figure 4. Predicted and measured AOD at wavelength 500 nm versus API were showed the discrepancy between them.

Similarly the interpolation method was then applied to predict AOD point by point for all API values obtained between August and September, 2012. As comparison can be done for these two different methods by using same data set. Additionally, both of these months were covered from the smallest to largest data point which available to conduct by interpolation technique. This procedure was directly conducted through programming software to predict the other months data from February to July, 2012. The result is shown in Fig. 5 where the blue/red line is the upper/lower limit of predicted AOD respectively from the predicting model. The green cross markers were the measured AOD from AERONET data. The predicted AOD by this interpolation technique was reasonably accurate predict for low API values and the error became higher as the API value increased.

The results in Figs. 4 and 5 also show over predicted of AOD at higher API value might be owing to the highest loading of aerosol amount occurred during August (refer to Table 1) and other reason was smoke from Indonesia blew toward Malaysia by southwest monsoon was uniformly distributed in the atmosphere. Even though during low API value predicted AOD can be matched with the measured AOD, sometimes underestimated value was produced by the model because the aerosol source was from local activity so that large variation could occur in the lower atmosphere. In order to identify these phenomenon, both predicted and measured AOD were plotted versus Julian days to show the AOD variation in the atmospheric column with time due to the change in the environment conditions (refer to Figs. 6 and 7 by interpolation and regression analysis technique respectively). This Figs. 6 and 7 also show similar trend of the predicted AOD with the measured AOD. Therefore, the similar trend proved that these models are reasonable accepted for AOD prediction. Nevertheless, as AOD is highly variable with time according to environmental activities, therefore by using only API

parameter should not be able to predict AOD accurately whereas this study reveal a new information that the discrepancy of the measured and predicted AOD can be use to estimate whether aerosol is generated by the local activities or is transported from other countries.

The AOD predicting model was generated based on the criteria proposed by [15-17] about aerosol may uniformly distributed in the low level of atmosphere as our ground truth data obtained showed similar trend in time variation (Fig. 7). However, when the aerosol is non uniformly distributed in the atmosphere the model can easily help to determine whether the atmosphere at high altitude is polluted by aerosol transported from other location or aerosol is mainly caused by the local activities.

Based on previous discussion, we conclude that regression method is more appropriate for analyzing future data set for all months. On the other hand, the interpolation method is more suitable for the dataset obtained only in August and September. Fig. 7, showing predicted AOD for all months, is generated based on regression method. In Fig. 7, two anomaly periods in the prediction AOD₅₀₀ was found. First, from Julian days 89 to 94 (29 March to 4 April 2012) shows the occurrence of under-predicted data; second, from Julian days 172 to 174 (20 to 22 June 2012) over-predicted values were obtained. For the first case, under-predicted AOD₅₀₀ was believed owing to very less polluted in the ground surface but certain pollutant must be existed in the higher altitude or in the upper atmosphere.

The pollutant found in the higher altitude was transported from north of Southeast Asia (especially Indochina) by the northeast monsoon at different altitude levels (refer to Fig. 8 a-c). Fig. 8 show the northeast monsoon forced to turn the westerly wind southward toward Penang and bring along the pollutant to the study site. For the second case, the high API values (more than 75) were highly over-predict value of AOD₅₀₀ (refer to Fig. 4) was due to nearly clear sky at the higher altitude of the atmosphere (no aerosol transported over the study area) because the source was mainly come from locally activities.

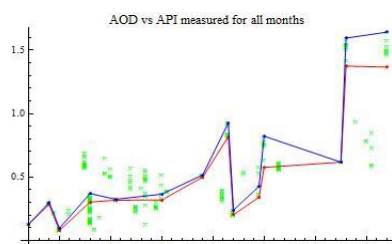


Figure 5. Predicted AOD was calculated from February to July of 2012 from the dataset in between August and September in the same year.

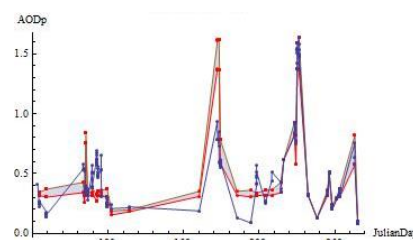


Figure 6. The predicted AOD band (red) by using interpolation technique and measured AOD (blue) versus Julian days was plotted.

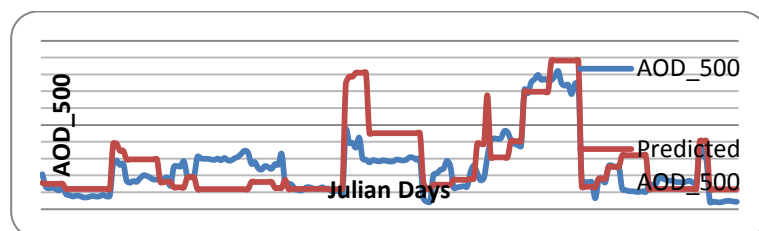


Figure 7. Predicted AOD by using regression analysis and measured AOD versus Julian days was plotted

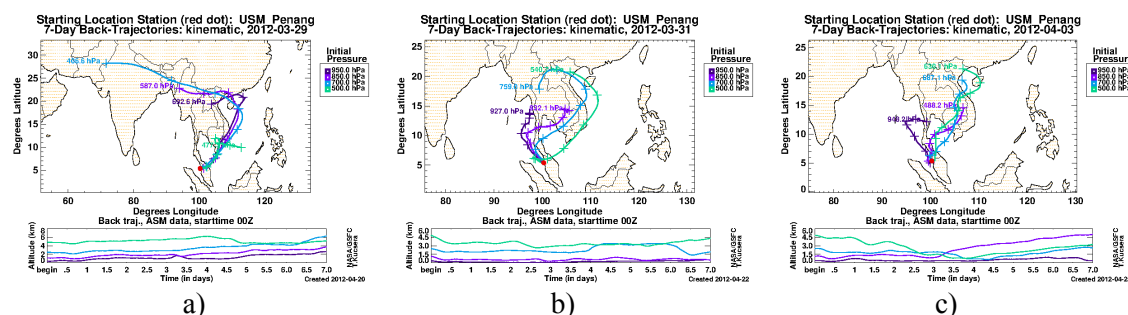


Figure 8. 7-back trajectory analyses were showed for a) 29 March, b) 31 March, and c) 4 April of 2012 at 00 Z. The back trajectory analyses starting at four pressures levels (950 hPa, 850 hPa, 700 hPa and 500 hPa) or these levels correspond to altitudes of approximately 0.5, 1.5, 3, and 5 kilometers, respectively at USM_Penang.

Table 1. AERONET Climatology table from quality assured data, Level 2.

2012 Averages of	τ_{a500}
Feb	0.31
Mar	0.45
Apr	0.27
May	0.25
Jun	0.72
July	0.31
Aug	0.73
Sep	0.38

4. Conclusion

The study showed both of the methods of regression and interpolation also can present whether aerosol transported in high altitude or from the local activities. But the result showed that the regression analysis was more suitable for this application than the interpolation method. Since only limited data set is available for this study so in order to determine the efficiency and accuracy of this generated model, further study using LIDAR system is needed. The weakness of this study was lack of the high resolution of vertical profile data to explain the exact aerosol distributed level.

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