Estimation of Ground Level PM2.5 by using MODIS Satellite data

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***Abstract*— Particulate matter (PM) in the atmosphere, is well-known adverse indicator on human health, especially fine particulate matter (PM2.5) reflected with respiratory and cardiovascular disease. High PM concentrations in the atmosphere impairs visibility and renders of bad quality air. The Punjab Environmental Protection Deptt. (EPD) has installed more than 8 ground stations for monitoring of PM 2.5 concentration in Lahore city. However, these stations cover only a limited area which leaves most of the land as unaccounted. To overcome such deficiency, satellite remote sensing MODIS product can be used as an alternative. Common statistical models and MODIS 10 km aerosol product are used to develop a relationship between PM2.5 and Aerosol optical depth (AOD). MODIS 3 km aerosol product is readily available since 2014 for estimation of PM 2.5. In this paper, the levels of PM 2.5 are determined by combining Aeronet AOD, MODIS AOD and ground based EPD PM 2.5 in Lahore city. MODIS 3km and 10 km products are used to extract all ground Aeronet stations pixel values and validated with Aerosol Robotic Network AOD (Aeronet AOD) for best estimation. Two variable method (TVM) or simple linear regression model is used to estimate PM 2.5 concentration. Results shows that the 10 km AOD product provide better estimation with higher R^2 values as compared to MODIS 3km product.**

Keywords—PM, EPD, AOD, TVM.

I. INTRODUCTION

Dust, haze suspended and smoke are atmospheric aerosols in the form of liquid and/or solid particles in the air from manmade or natural sources. It mainly occurs in tropospheric and stratospheric layers. Aerosols includes various phenomenon like dust, haze, mist, fumes, smoke, cloud, fog and smog. Aerosols are a constituent of air pollution and smog [1], [2] and consequent change of climate, hydrological cycle, microphysics of cloud and global sulfur, nitrogen and carbon cycles directly or indirectly [3], [4]. These particles might be reduced visibility as well as affect human health [5]. Spatial and temporal dispersion of aerosols is more important in the context of air quality [6]. The variations in the atmospheric aerosol, land surface properties, greenhouse gases, solar radiations and climate alter the energy balance of the Earth's atmospheric system [7], [8]. Aerosols are combination of particles and these are recognized by their formation, size and chemical composition [9]. Whereas, Fine particulate matter has been reported as a severe health hazard [10]–[12]. Scientific studies reported PM2.5 link with cardio respiratory, mutagenic, lung and mortality diseases.[13]–[17]. The particulate matter can be emitted from anthropogenic and natural sources [18], [19] or can be produced from the gaseous pollutants. Common pollutant sources of PM2.5 are burning of woods, Garbage, Bush fires, Open burning, Vehicles, and point Location sources such as industrial and power plants. In metropolitan cities PM2.5 is normally link with automobile and local emissions. These are the primary sources of PM2.5 while the chemical transformation are recognized as secondary source. [20]. Fine Particulate matter directly affect the energy budget, precipitation, atmospheric visibility, surface temperature, and indirectly affects the climate by changing the cloud optical properties. This creates uncertainties in prediction of climate change [21]–[23]. The countries with urban growth and industries are specially confronted with high amounts of suspended particles in atmosphere. According to World Health Organization (WHO), in Pakistan atmospheric pollution is deteriorating the air quality with the passage of time [2]. Field Monitoring are time and cost consuming activities, while satellite based air pollution measures offer the global coverage. The aerosol monitoring through satellite remote sensing started in the mid 20 century to observe the particles of desert over the ocean [22]. The 0.63 μm channel of NOAA-AVHRR satellite was used for production of Aerosol Optical Depth (AOT) maps over the ocean [9]. The spectrum range for aerosols particles in remote sensing are mostly restricted because of gaseous absorptions and ozone. Anthropogenic aerosols (SO_2, organic gases, haze and smoke) are mainly produced from vehicle and industrial emissions. Loss of solar irradiance is due to the sulphate aerosols produced by anthropogenic sources. Lifetime of the aerosols varies in days to hours and in minutes as per the particles size. stratospheric aerosols have years of living in volcanic eruption [24]. The aerosols are geographically separated as urban, remote continental, rural, maritime, background aerosols and desert dust [25].

II. OBJECTIVE

Overall, the intention of this research is to explore the Remote Sensing datasets and Statistical model for estimating the PM 2.5 mass concentration in the Lahore city for the year of 2018.

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III. MATERIELS AND METHODS

A. Study Area

The Lahore is selected for the study area because it is the Pakistan's second largest metropolitan city and have dense population, high growth rate and rapid spatial expansion. The air pollution is high due to industries, anthropogenic activities and heavy traffic. The reference map of Lahore is shown in figure (1).

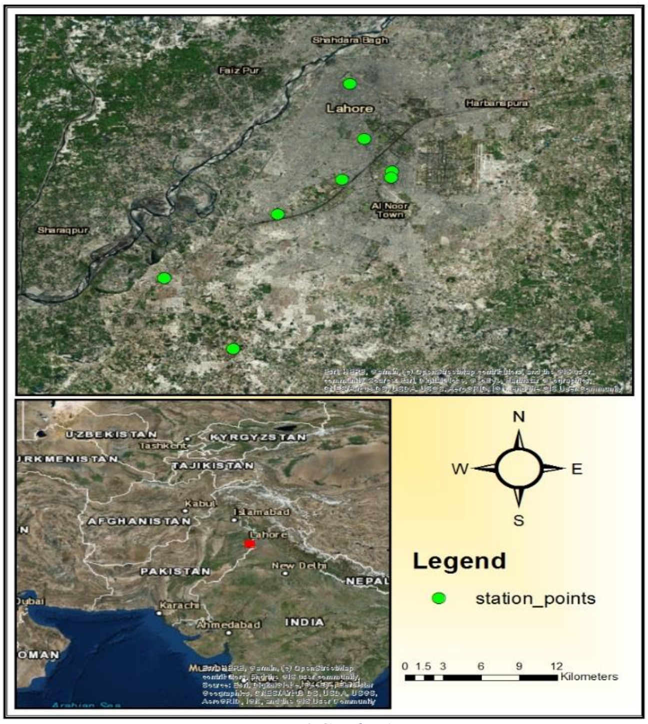

Figure 1 Study Area

B. Data collection

1) MODIS 3km and 10km sensors data

As per geographic features, aerosols vary on different scales. The MODIS 10km AOD product are good related to climate applications. However, it's not good enough for fine scales study (Leigh et al.,2014). Consequently therefore, MODIS 3km AOD product was released in 2014 as a collection of 6 product (MOD04_3K and MYD04_3K). MODIS 3km AOD product can help to show more variation than 10km AOD product (figure 2). The missing grids are mainly due to snow, cloud and ice cover or other reasons. MODIS AOD are stored in format of Hierarchical Data Format (HDF).

To evaluate performance of 10km and 3km product for the estimation of AOD and measurement validate form Aeronet

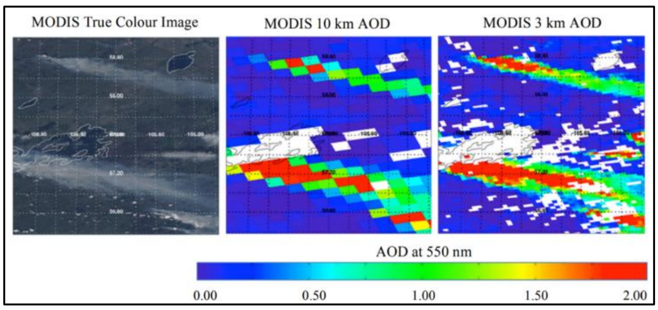

Figure 2 MODIS true color image, 10km and 3km AOD image comparison

AOD. Two stations of Aeronet AOD have been built in Karachi and Lahore, Pakistan. In this study, Lahore station data is used.

Aeronet AOD inversion product has three levels of quality: Level 1 (unscreened data), Level 1.5 (Cloud screened data) and Level 2 (pre and post ground standardization applied, cloud examined data, and certified data) [26] Whereas, Level 1 and Level 1.5 are not certified. Therefore, Level 2 data is used.

2) Ground Level PM 2.5 Measurements

PM2.5 daily averaged data was acquired from Pakistan Environmental Protection Agency (EPA) site located in Lahore [27].

IV. METHODOLOGY

The methodology contains three modules, Validation of AOD, pre-processing of data and construction of model. At first, validation of AOD was to formalize the MODIS AOD product with the Surface level AOD to assess 3km and 10 km AOD products performances at different pixel sizes. The pre-processing of data module was used to pre-process the satellite data for model construction. In last, the TVM models were built to decide the PM 2.5 mass concentration and investigate its spatial distribution.

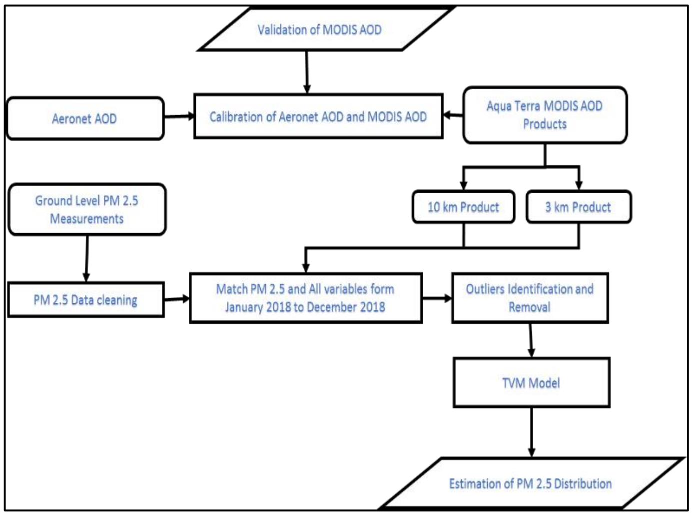

Figure 3 Methodology Flow Chart

V. RESULTS

A. MODIS AOD Validation

Firstly, the MODIS AOD products at 10km and 3km resolutions are compared and validated by Aeronet AOD measurements after temporal and spatial matching at Lahore site 89 and 82 collocation, respectively. MODIS 3km and 10 km AOD with Aeronet observations. Different seasons are presented in the timeline of MODIS and Aeronet AODs. The autumn season is almost missing due to unavailability of data. Some data duration is lost for both 3km and 10km products. The high concentration is mainly observed during winter season, and low concentration are found in summer and spring seasons (figure 4).

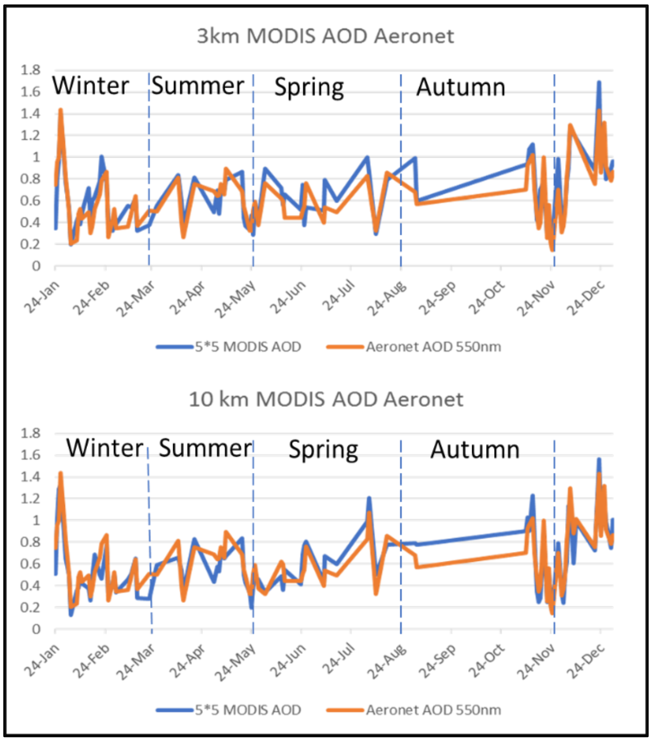

Figure 4 Timeline of MODIS AOD at 3km and 10 km and Aeronet AOD at 550nm

B. Comparison of MODIS and Aeronet at 550 nm

Estimation of AOD on whole study area scatter plots are drawn between the product of MODIS 10km and 3km with Aeronet data. Figure (5) presents the scatter plots which show the collocation of MODIS and Aeronet AODs, dotted lines showing trends. Both 10km and 3km products are shown higher correlations with Aeronet data.

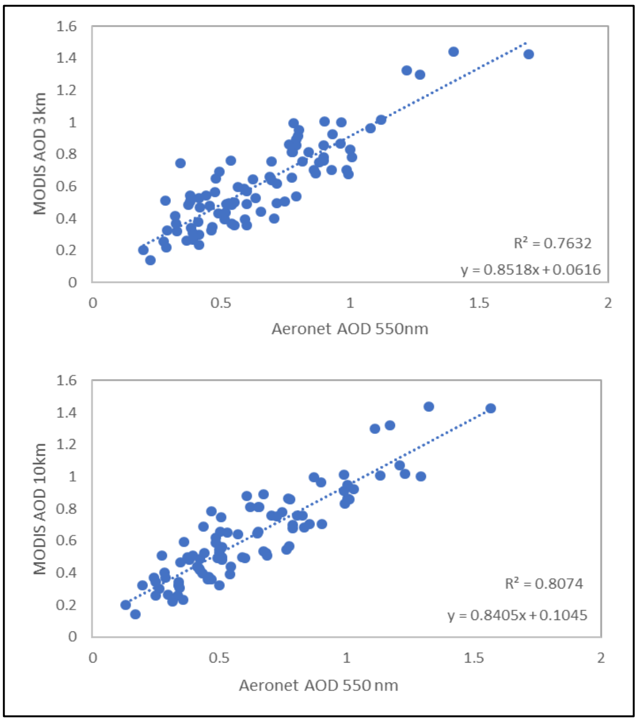

Figure 5 Scatter plot between MODIS 10km and 3km product with Aeronet data at 550nm

C. Two Variable Method (TVM) or Simple Linear Regression Model

Firstly, the ground Aeronet AOD at 550nm were correlated with ground level PM 2.5 which shows the R-square values of (0.57) with a slope of (135.05) and intercept of (20.71) as shown in figure (6). The slope and intercept were used to estimate the PM 2.5 at ground level with the help of MODIS AOD- Aeronet AOD measurements. The correlation of estimated PM2.5 which was measured by the 10km calibrated AOD with surface level PM 2.5 show R^2 (0.47) with slope of (0.376) and intercept of (65.68) as shown in figure (7). The correlation of estimated PM 2.5 form 3km calibrated AOD with surface level PM 2.5 mass concentration show R^2(0.34) with slope of (0.376) and intercept (65.68) as shown in figure (7). Estimation of PM 2.5 with 10km calibrated AOD shows a good relationship as compared to the estimation of PM 2.5 with 3km calibrated AOD with surface level PM 2.5. The estimation of PM 2.5 with ground level AOD would be acceptable, whereas with the estimation of calibrated AOD for both 10km and 3km products would not be acceptable because of the low coefficient of relation.

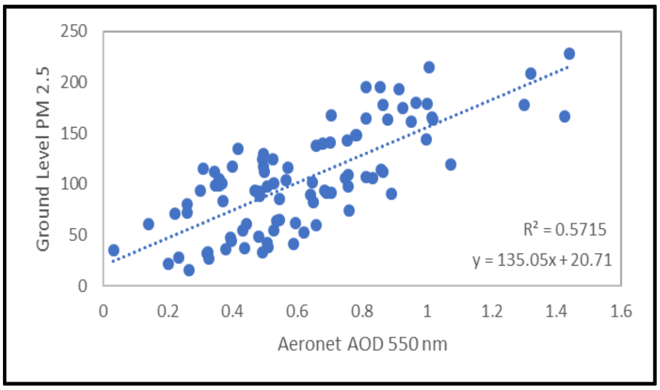

Figure 6 Scatter plot of Aeronet AOD against field level PM 2.5 measurements

VI. Conclusion

PM 2.5 mass concentration is estimated by the 10km and 3km MODIS AOD products. By comparing the 10km and 3km MODIS AOD product, it is founded that 10km AOD product which shows good accuracy among all of the others in PM 2.5 estimation. However, the spatial coverage of 10km AOD product is greater than the product of 3km AOD in derived PM 2.5 mass concentration estimation. This is not only because of its resolution, but both products also contain different algorithms. Moreover, the 3km MODIS AOD product performed good in the presentation of its spatial variation, which help to identify the sources of emission.

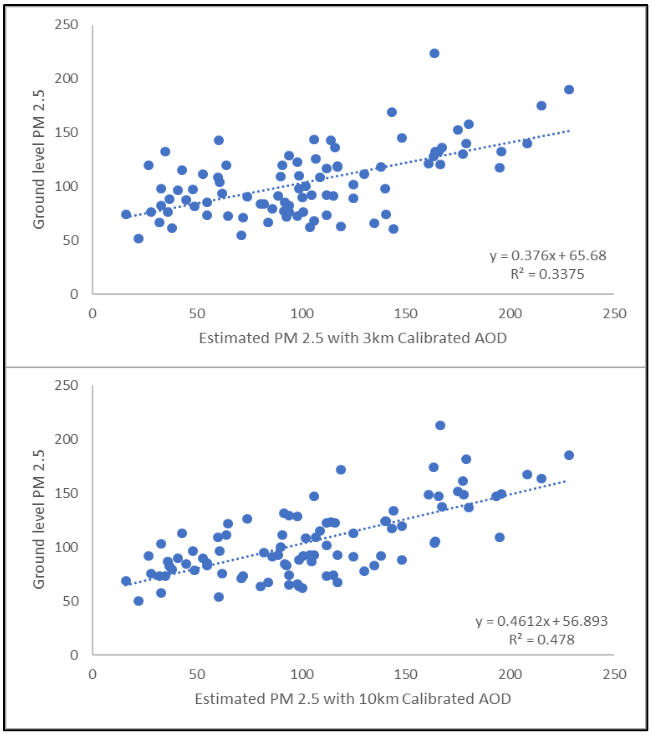

Figure 7 Scatter plots for the Two variable models results between the predicted and ground level PM 2.5 mass concentration from 10 km AOD model

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