Mapping PM 2.5 Concentration with Satellite Based Remote Sensing Technology: A Case Study of Kathmandu, Nepal

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Abstract

Air pollution has become a major issue of modern metropolitan because of industrial emission, urbanization and anthropogenic activities. Many air quality monitoring stations are established for measuring the pollution but these stations tend to be scarcely distributed and do not provide sufficient tools for mapping atmospheric pollution since air quality is highly variable. Satellite remote sensing is a valuable tool for assessing and mapping air pollution as satellite images are able to provide synoptic views of large areas in one image on a systematic basis due to the temporal resolution of the satellite sensors. This article investigates the relationship of PM 2.5 concentration an air pollution pattern with urban land use and with urban thermal landscape using a Remote sensing approach. Aerosol Optical Depth (AOD) being the measure of aerosols (e.g., urban haze, smoke particles, desert dust) distributed with in a column of air from the instrument (earth's surface) to top of the atmosphere plays an effective role to alter the earth's energy balance and hence the climate. The research focuses on relating satellite based AOD retrieval with the ground-based PM concentration. The European Satellite Agency (ESA) sentinel 5P aerosol index was used as satellite imagery for this research. Relationships among the spatial patterns of air pollution, with ground-based observation were sought through python and correlation analyses. Therefore, using better mathematical model air pollution assessment of place is detailed rather than virtual station.

Keywords: remote sensing, sentinel, aerosols, particulate matters, model.

1 Introduction

1.1 Background

The International Agency for Research on Cancer (IARC) classified particulate matter, the main component of outdoor pollution, as carcinogenic for humans. PM2.5, particulate matter less than 2.5 m in an aerodynamic diameter, is generally referred to as fine particles and has been implicated in human health problems (P.C. Mannis, 1979). In developed countries many complex numerical simulations have been carried out in valleys to control air pollution. However, many developing countries are still struggling to gain a clear understanding of pollutant dynamics even at a basic level. Due to the high variable nature of air quality the use of air quality monitoring stations is not enough to monitor atmospheric pollution (Wald, 1999).

The use of earth observation to monitor air pollution in different geographical areas and especially in cities has received considerable attention as it provides synoptic views of large areas in one image on a systematic basis due to the temporal resolution of the satellite sensors (Hadjimitsis, 2002). This study focuses on developing a relation between satellite derived aerosol depth and PM 2.5 from ground station.
Mapping the relationship between satellite data and ground-based PM 2.5 concentration is achievable through regression techniques. Due to the presence of various air pollutant factor at the same it is very challenging for regression techniques to model such a complex relationship. The proposed solution aims at developing a modelling method for mapping PM 2.5 using satellite retrieved aerosol data as it provides a dynamic range for the study rather than scarcely distributed stations.

1.2 **Objectives**

Primary objective:

- To model the concentrations of the pollutant's parameters ($PM_{2.5}$) in air using AOD.

Secondary objectives:

- To calculate the Aerosols Optical Depth (AOD) using sentinel data.
- To predict the rate of air pollution according to temporal and spatial variation.

1.3 **Study Area**

The research is focused on 3 major cities Kathmandu, Bhaktapur, Lalitpur located in Kathmandu valley, Bagmati province of Nepal. The cities are the most populated and polluted cities of the country. Kathmandu has been ranked as 8th most polluted city in the world (the 2018 world air quality report). As the valley is surrounded by high hills and mountains. The air pollutant become trapped and accumulate in the valley without dilution by vertical dispersion.

Figure 1. Study Area

2 Methodology

Sentinel 5P level 2 aerosol index 3.5*7 km spatial resolution satellite data is downloaded from Copernicus Open Access Hub website. The daily basis satellite data from January 2019-January 2020 is used. For the PM 2.5 concentration, daily AQI data of same dates is retrieved from acqin.org website of 4 different stations of Kathmandu valley which were converted to PM 2.5 using mathematical relations. After atmospherically correcting the satellite data haversine formula is used to determine AOD values at nearest point of PM 2.5 observation stations' location. Python programming is used to retrieve the AOD values of different location. The AOD values retrieved are validated using AOD lookup tables. The AOD retrieved are correlated with the PM 2.5 ground observation data using regression techniques. Finally, a linear mathematical model was developed for determining the PM2.5 values of any location using satellite AOD data. The basic methodology flowchart is shown in Figure 2.

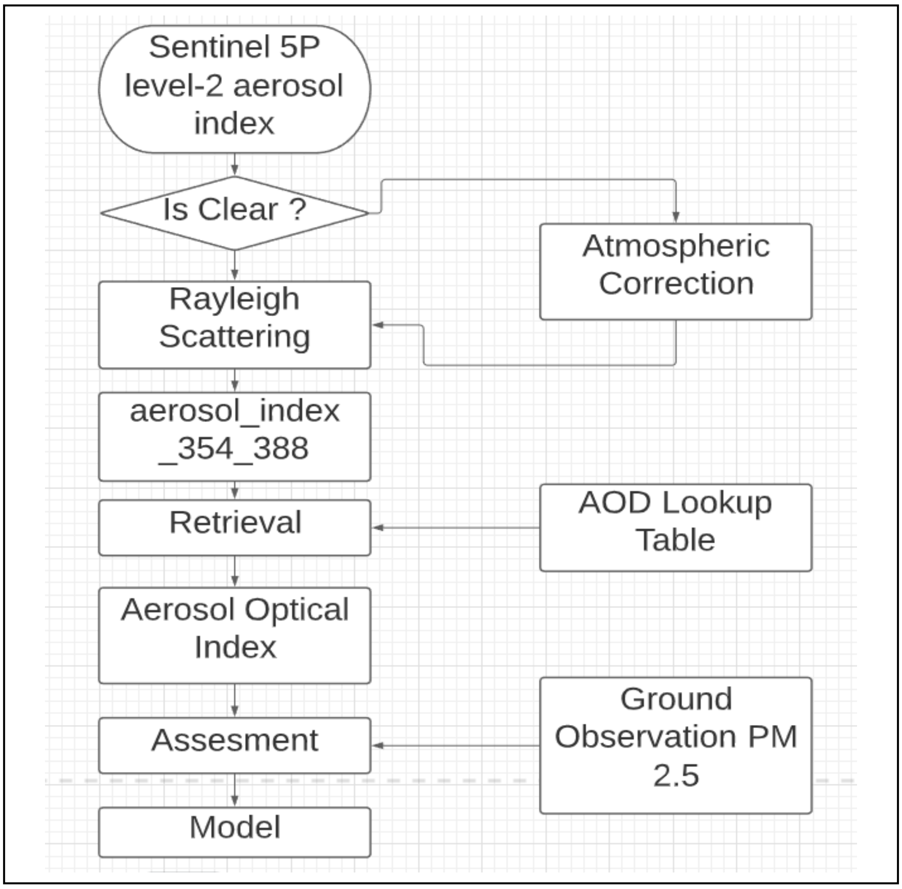

Figure 2. Basic methodology

3 Result and Conclusion

A linear model Equation 1 is developed for estimating PM 2.5 from satellite retrieved AOD. Ground PM 2.5 data was correlated with satellite retrieved AOD to estimate satellite-based PM 2.5 concentration. The correlation between AOD and PM 2.5 is found to be 0.92.

$$Y = 3482 * X - 39.396 \tag{1}$$

Where:

- Y – is the PM 2.5 retrieved,
- X – is the aerosol index

Figure 3 shows the line chart of ground observation PM 2.5 and model retrieved PM 2.5 of station US Embassy, Nepal from January 2020 to June 2020. From the figure it can be clearly seen that both PM 2.5 data seems to same. The difference of PM 2.5 value obtained from satellite observation from ground obtained PM 2.5 is found to be within the range of 10.

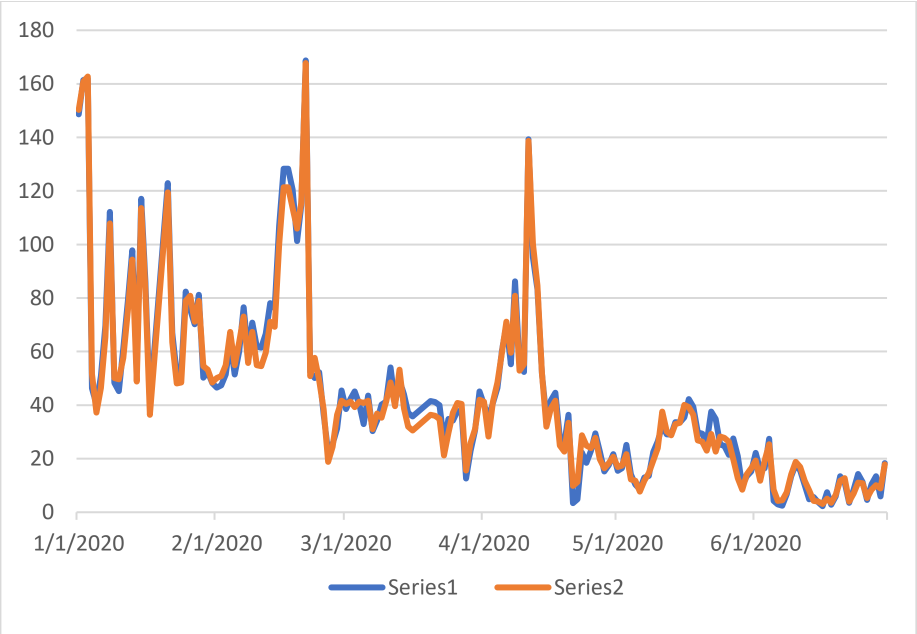

Figure 3. line chart where series 1 is the ground observation PM 2.5 concentration and series 2 is the satellite derived PM 2.5 concentration

The Figure 3 also shows the air to be unhealthy in the months January, February, March and satisfactory in the months may, June. Therefore, it can be concluded that the model works well in determination of PM 2.5 concentration from satellite aerosol values. Thus, it is efficient to use satellite data for PM 2.5 concentration as it provides a more synoptic view of large area in one image in a systematic basis rather than the unevenly distributed PM 2.5 ground observation.

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