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**IIT Delhi**  
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Arabian  
Sea  
Arabian  
Basin

Bay of  
Bengal

Andaman and  
Nicobar Islands

Andaman  
Sea

Carlsberg R.

area

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# A LONG TERM SATELLITE BASED STUDY OF AEROSOL EFFECTS ON VISIBILITY OVER THE CAPITAL CITY OF ASSAM, GUWAHATI

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**KEYWORDS:** AOD, Remote Sensing, Visibility, Air Quality

## INTRODUCTION

Satellite remote sensing technique provides a primary tool to understand the role of atmospheric aerosol particles in Earth system science as well as climate (Reid *et al.*, 2013). Satellite data of pollutants in the atmosphere are becoming more extensively used in the decision-making as well as environmental management activities of public, private sector and non-profit organization (Duncan *et al.*, 2014). Remote sensing techniques are a very helpful tool for understanding Earth processes as well as evaluating performance of model predictions on weather and climate change. Instruments mounted on satellites can provide the spatial distribution of atmospheric aerosol; trace gases etc. on regional as well as global scale. In field experiments, data are usually available for some selected locations; hence satellite remote sensing fill the need for extensive data of atmospheric pollutants with greater temporal and spatial coverage than aircraft campaigns. The impact of pollutant on radiative balance, air quality and human health has led to significant attempt to measure atmospheric aerosols and trace gases by using ground based networks along with satellite observations. Proper evaluations of aerosols in addition to trace gases are necessary for the in progress global climate simulations because they play as vital components for Earth's climate change process.

Over recent years, a large number of long-term variation trends in atmospheric aerosol have been conducted by using Moderate Resolution Imaging Spectroradiometer (MODIS) data over different places in the world (Levy *et al.*, 2010, 2013; Guo *et al.*, 2011; Soni *et al.*, 2015; Dahutia *et al.*, 2017 etc.). Over vegetated land, MODIS retrieves Aerosol Optical Depth (AOD) at 3 visible channels with high accurateness, i.e.,  $\pm 0.05 \pm 0.2\tau$  (Remer *et al.*, 2005). The retrieved uncertainty of MODIS AOD at 550 nm is estimated to be  $\pm (0.05 + 0.15 \text{ AOD}_{550})$  over land (Remer *et al.*, 2005, 2008; Levy *et al.*, 2013), but accuracy may be lower for some particular regions of the world depending on the assumptions on type of surface along with optical properties of aerosols. Visibility is a simply observable indicator of air quality over a region (Bäumer *et al.*, 2008): a high visibility generally means good air quality (Horvath, 1995). Clear sky visibility is reduced mainly by the presence of aerosols, whose types along with concentrations have an enormous impact on the amount of incoming solar radiation that reaches the surface of Earth (Wang *et al.*, 2009). A number of earlier studies on correlation of visibility or else visual range and aerosol properties were reported by Bäumer *et al.* (2008). According to Wang *et al.* (2009), visibility has decreased considerably since the mid-1980s over South and East Asia, South America, Australia, and Africa except Europe resulting in net global dimming over land.

The main goal of the present study is to assess the long term temporal distributions of atmospheric aerosols over Guwahati, North-East India for the period of January 2004 to December 2016. This study area is of importance with regard to air pollution due to the large population, unique topography and considerable sources of natural and anthropogenic emissions. Also, in this paper, we present the results of relationship between AOD and horizontal visibility to assess the atmospheric pollution of the study area.

## DATA SOURCES

The moderate resolution imaging spectroradiometer (MODIS) sensor on board the NASA Earth Observing System (EOS) Terra and Aqua satellite based AOD data at 550 nm data are used for the period of January, 2004-December, 2016. The daily Level 3 data set of aerosol optical depth (AOD) at 550 nm and Ångström exponent (AE) with quality assured (QA) Collection 6 data has  $1^\circ \times 1^\circ$  global resolutions (Levy *et al.*, 2013). For the present study, daily mean level-3 collection-6 MODIS AOD data sets (both Terra and Aqua) are obtained from the Giovanni web service (<http://disc.sci.gsfc.nasa.gov/giovanni>) on a  $1^\circ \times 1^\circ$  spatial resolution, centred at the study location.

## RESULTS & DISCUSSIONS

To examine the day-to-day variability of AOD over Guwahati, daily mean Aqua AOD at 550 nm for the 13-year period is plotted as shown in Fig. 1. The solid straight line in the figure corresponds to the linear best fit to the daily mean data of AOD. It is clearly seen from the figure that a significant long-term increasing trend of AOD exists over Guwahati which may be due to decreasing trend of monthly (mainly pre-monsoon and monsoon month) rainfall for the study period.

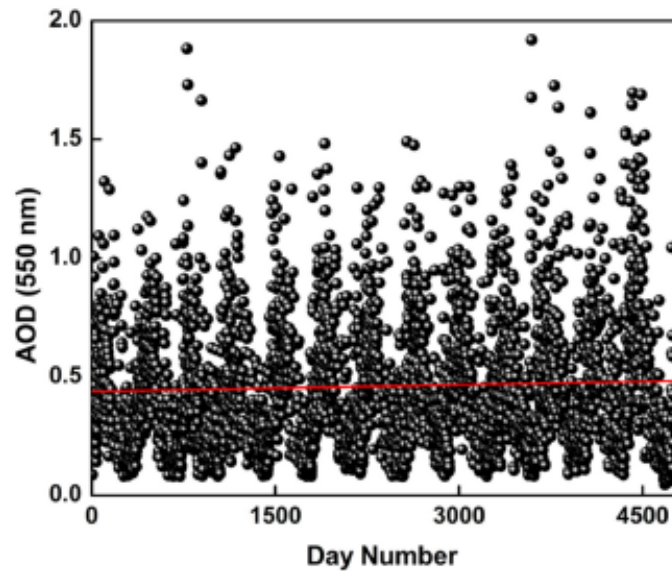


Figure 1. Day-to-day variability of daily mean Aqua AOD at 550 nm over Guwahati for the period of January 2004 to December 2016. The solid red straight line is the linear best fit to the daily mean data.

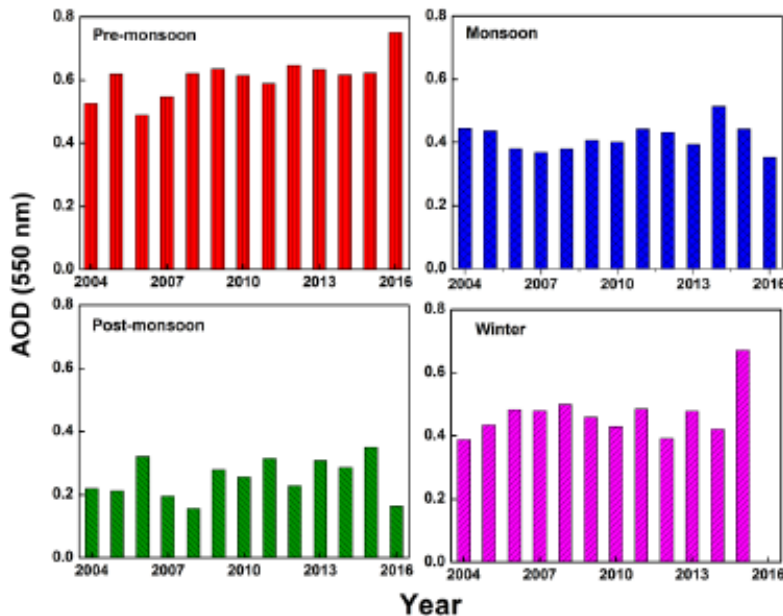


Figure 2. The seasonal variation of AOD at 550 nm over Guwahati for the period of January 2004 to December 2016.

The seasonal variation of AOD at 550 nm over Guwahati for the period 2004 to 2016 is shown in Fig.2. It shows highest value during pre-monsoon (March-May) season due to the intense biomass burning activities and lowest in post-monsoon (October-November) season mainly due to wash out of aerosols by rain in the preceding months without enough replacement. The seasonally averaged AOD reached its maximum in pre-monsoon ( $0.61 \pm 0.06$ ), followed by winter (December-February) ( $0.47 \pm 0.07$ ) and monsoon (June-September) ( $0.41 \pm 0.04$ ), with the minimum occurring in post-monsoon ( $0.25 \pm 0.06$ ) season. Strong seasonality in AOD was reported by Biswas *et al.* (2017) with a peak in pre-monsoon and dip in post-monsoon over nine different locations in North-East India and adjoining areas. Dahutia *et al.* (2017) also reported prominent longitudinal gradient in seasonal aerosol distribution over North-East India with higher AOD values in the western part (including Guwahati), which is mainly attributed to variability of source types and closeness to the western influences through transportation (Pathak *et al.*, 2014, 2016; Gogoi *et al.*, 2017).

The relative dominance of fine mode aerosols over the coarse mode can be determined from Ångström exponent. The value of the Ångström exponent is a qualitative indicator of size of aerosol particles (Ångström, 1929). Values of Ångström exponent  $\leq 1$  indicate size distributions dominated by coarse mode aerosols that are usually linked with dust and sea salt whereas values of Ångström exponent  $\geq 2$  indicate size distributions dominated by fine mode aerosols which are generally associated with urban pollution and biomass burning (Eck *et al.*, 1999). The monthly variation in Ångström exponent with Aqua AOD over Guwahati for the period January, 2004 to December, 2016 is shown in Fig.3. The monthly average AOD value varies from its highest value ( $0.63 \pm 0.09$ ) in the month of March to its lowest value ( $0.23 \pm 0.05$ ) in October for the study period over Guwahati. Ångström exponent value lying between 1 and 1.5 indicates major contributions from accumulation mode aerosols to the AOD (Beegum *et al.*, 2009). The observed Ångström exponent value varies from its minimum value ( $1.18 \pm 0.05$ ) in monsoon season to its maximum value ( $1.35 \pm 0.09$ ) in post-monsoon season. This in fact indicates size of aerosol particles in post-monsoon season is smaller than that in monsoon season.

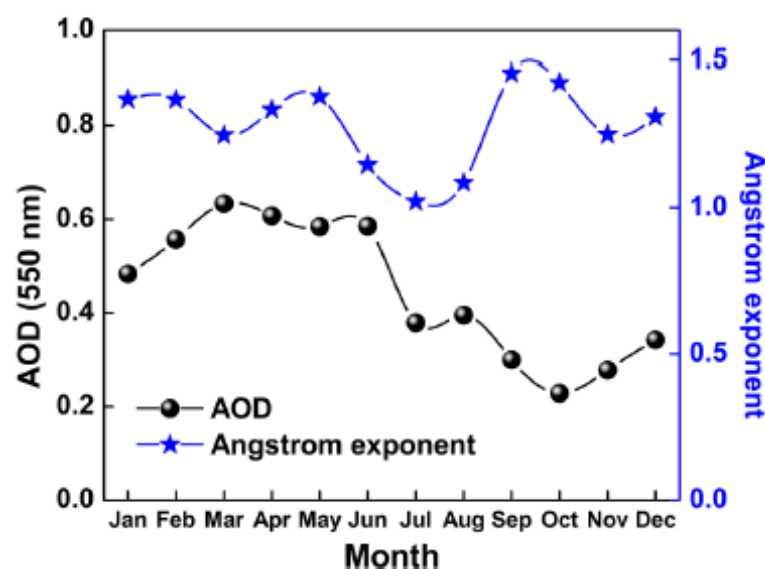


Figure 3. The monthly variation in Aqua AOD and Ångström exponent over Guwahati for the period of January, 2004 to December, 2016.

A relationship between visibility (V) and aerosol optical depth has been established by Vermote *et al.* (2002) to be used for *Visible Infrared Imaging Radiometer Suite (VIIRS)* data onboard the National Polar-orbiting Operational Environmental Satellite System:

$$V = 3.9449 / (AOD_{550} - 0.08498) \dots \dots \dots (1)$$

This equation is not valid for  $AOD \leq 0.08498$ .

The relationship between AOD and visibility is presented in Fig.4. The analysis showed that visibility is minimum during pre-monsoon months which are mainly due to higher values of AOD for the

season over the study region. A higher value of AOD represents higher column of aerosol loading in the atmosphere which scatter off light more effectively and hence resulting in lower visibility (Wang and Christopher, 2003). The monthly average visibility in Guwahati is highest (27.5 km) in October with a moderate reduction observed during the monsoon, reaching a minimum of 7.2 km in March. During winter month, local aerosol emissions are trapped within the boundary layer leading to higher surface concentrations and hence resulting lower visibility.

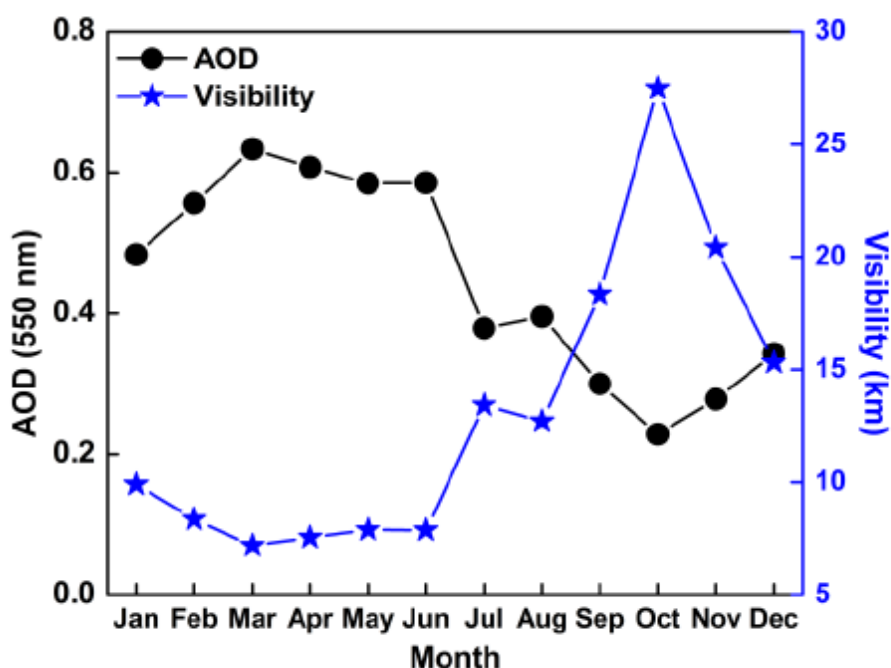


Figure 4. The monthly variation in Aqua AOD and visibility over Guwahati for the period of January, 2004 to December, 2016.

## CONCLUSIONS

In this study long-term (January 2004–December 2016) variations of AOD and Ångström exponent have been studied by using satellite observations. For all the year of observations, the seasonal variation of AOD shows highest value during the pre-monsoon season and lowest in post-monsoon season over Guwahati. The seasonally averaged AOD reached its maximum in pre-monsoon ( $0.608 \pm 0.06$ ) season, followed by winter ( $0.469 \pm 0.07$ ) and monsoon ( $0.415 \pm 0.04$ ), with the minimum occurring in post-monsoon ( $0.253 \pm 0.06$ ) season. The observed Ångström exponent value varies from its minimum value ( $1.18 \pm 0.05$ ) in monsoon season to its maximum value ( $1.35 \pm 0.09$ ) in post-monsoon season which indicates size of aerosol particles in post-monsoon is smaller than that in monsoon season. The monthly average visibility in Guwahati is highest (27.5 km) in the month of October with a moderate reduction observed during the monsoon, reaching a minimum of 7.2 km in March. With increasing AOD values, horizontal visibility decreases over Guwahati.

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