Retrieval of aerosols extinction coefficient from calipso satellite observations: a case study over Bhubaneswar

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Abstract. In order to examine the effects of aerosols on climate, knowledge on vertical distribution of aerosol in the lower atmosphere is essential. We analysed aerosol extinction coefficient obtained from the Cloud-Aerosol Lidar Infrared Pathfinder Satellite Observations (CALIPSO) on board Lidar at campus-3 of KIIT-DU Bhubaneswar during July 2018 to June 2019. Seasonal average (± standard deviation) of extinction coefficient for the winter (December-February: DJF), summer (March-May: MAM), monsoon (June-August: JJA) and post-monsoon (September-November: SON) are found to be 0.22±0.13, 13.08±0.07, 0.27±0.05, 0.15±0.14 km⁻¹, respectively. To differentiate the aerosol loading between the surface and elevated layer, we averaged extinction values for below and above 1km height. At surface level, the values were found to be maximum in post-monsoon (0.54±0.13 km⁻¹) and minimum (0.14±0.03 km⁻¹) in winter. Whereas at elevated level, the values exhibit maximum in monsoon (0.45±0.45 km⁻¹) and minimum (0.11±0.02 km⁻¹) in post-monsoon. The vertical profile of aerosol can be used to anticipate aerosol extinction simulations over a variety of time periods and in regions where the CALIOP cannot reach.

Keywords: CALIPSO; extinction coefficient; vertical aerosol profile; surface level; elevated level

1. Introduction

By absorbing and dispersing incoming solar energy in the atmosphere, aerosols contribute to surface heating and cooling. Rapid industrialization and urbanization are responsible for the increase of aerosol content. To evaluate the effects of aerosols on the atmosphere, columnar distribution of particles is required. Aerosols, along with cloud characteristics and the Earth’s radiation budget, play an important role in climate change [1]. The optical characteristics of elevated aerosol layers can be affected by long-range transport at any place [2][3]. Researchers investigated seasonal variability of vertical distribution and extinction profiles using the CALIOP level 3 product [4][5]. It provides global aerosol source attribution [6] and vertical distribution of aerosols relating to atmospheric circulation [7]. They reported about the monthly and seasonal values of aerosol extinction coefficient of backscatter at 532 nm similar to our study. The difference of aerosol concentrations differs at different altitudes due to difference in columnar levels of aerosol at various heights [8]. [9] have discussed about the presence of dust layers in altitude of 4 to 6 km in north western India analysing about the vertical profiles of aerosol extinction. This effect is necessary to analyse the impact on climate change and effect on environment [10]. Similar observations have been reported by [11] and [12]. [13] have analysed about higher concentration of aerosol in winter [14] in Indo-Gangetic.
plain as observed in our study. [15] have analysed about higher aerosol values in winter were due to crop burning. The goal of this study is to look into the vertical distribution of aerosols throughout the seasons and determine the impact of meteorology on aerosol and climatic impact at a given place. Bhubaneswar is one of the most rapidly rising cities in terms of infrastructure, technological innovation, greenery, and attempts to achieve smart city status.

2. Methodology

The Level 2.0 data of extinction coefficient was obtained from repository of onboard Lidar based satellite of Cloud-Aerosol Lidar Infrared Pathfinder Satellite Observations (CALIPSO) observations. The horizontal resolution of the satellite observations was 40 km resolution and 0.06 km vertical resolution for profile products at all altitudes.

2.1. Study site

Study site is situated at a latitude of 20.35°N and longitude of 85.81°E in campus-3, KIIT-DU Bhubaneswar at a height of 10m above ground level. Detailed description about the site is explained elsewhere [16].

2.2. Back trajectory analysis

The 7-day back-trajectory information was obtained from NOAA-Hybrid Single Particle Langrangian Integrated Trajectory (HYSPLIT) model by using the surface and elevated level back trajectory at heights of 10, 100, 500, 1000, 2500 and 5000 metre respectively to know the direction of the trajectory in all seasons.

3. Results and discussion

Month-wise aerosol extinction coefficient, that represents aerosol attenuation property, for four seasons in Bhubaneswar between July 2018 to June 2019 are as shown in Figure 1. September received highest attenuation (0.31±0.4 km⁻¹) suggesting that this month receives highest air pollution at surface level after the intense monsoon season ends. On the other hand, monsoon month August receives lowest attenuation (0.13±0.04 km⁻¹) due to the rainout or washout in the atmosphere. Seasonal average of extinction coefficients exhibits highest in post-monsoon (0.28±0.04 km⁻¹) followed by winter (0.22±0.07 km⁻¹), summer (16±0.04 km⁻¹) and lowest in monsoon (0.14±0.01) as referred as in Figure 2. The accumulation of aerosols at
surface during post-monsoon season makes it highly polluted, particularly at surface level (0.54 km\(^{-1}\)) the extinction value shows 5 times higher than that at elevated level (0.11 km\(^{-1}\)).

Analysis of level wise aerosol attenuation and back-trajectory analysis is required to know about the possible transport and possible emanation of emissions from various origins, respectively. Surface and elevated level aerosol attenuation were categorized through averaging the extinction coefficient values for below and above 1 km, respectively (refer Figure 3). At surface level, peak value was observed in post-monsoon with 0.54±0.13. It indicates that the season after the monsoon such as post-monsoon receives relatively higher aerosol loading at surface level compared at

![Figure 2](image-url). Vertical distribution of seasonal average (Standard deviation) of extinction coefficient observed from CALIPSO satellite retrievals at study location during July 2018 to June 2019

![Figure 3](image-url). The extinction coefficient averaged for each season at (a) surface level: below 1 km (b) elevated level: above 1km that observed from CALIPSO satellite retrievals at study location during July 2018 to June 2019
elevated level. Whereas, a lowest value observed in winter with 0.14±0.03 km$^{-1}$, owing to the accumulation of aerosols at the surface followed by less convective transport in winter provides less aerosol loading, particularly at surface level. It is also supported by air-mass trajectories that exhibits scattered origins of pathways at elevated level compared of surface level where accumulation of pathways over possible source regions of eastern India and central India (refer Figure 4 and Figure 5). This indicates that elevated level transport is predominant in winter. This is reasoned by the trajectory analysis where airmass pathways traversed from elevated level (<1km) spent more time over aerosol hot spots of India including Indo-Gangetic region and central India followed by long-range sources such as west Asia (refer Figure 4 and Figure 5).

**Figure 4.** Air-mass pathways traversed from elevated levels (1000, 2500 and 5000m) of the receptor (study) location towards backward source origins observed at study location during July 2018 to June 2019

**Figure 5.** Same as Figure 4, but from surface level (10, 100 and 500m).
4. Conclusion

We conclude that the satellite observations of aerosol attenuation (e.g., extinction coefficient) showed highest in post-monsoon, which received aerosols at surface level relatively higher than that at elevated level. Back trajectory analysis was also corroborated with the satellite observations. Local weather effect was observed in monsoon season, where seasonal average extinction coefficient value was less that likely to receive highest rainfall in entire year.

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5. References

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Appendix
Figure A1. Scaled, color-modulated, altitude-time images of CALIPSO for aerosol subtype for (a) monsoon (b) post-monsoon (c) winter (d) summer.