International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(Research Article)

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Analysis of aerosol characteristics over Ballari, India using MODIS Data

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International Journal of Science and Research Archive, 2025, 14(01), 168-173

Publication history: Received on 28 November 2024; revised on 03 January 2025; accepted on 05 January 2025

Article DOI: https://doi.org/10.30574/ijsra.2025.14.1.0020

Abstract

Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data was used to investigate the temporal variations of Aerosol Optical Depth (AOD) over Ballari from Jan 2020 – Dec 2023. During the study period the monthly mean aerosol optical depth (AOD) at 500 nm ranged from 0.25 ± 0.12 to 0.75 ± 0.18. High mean Aerosol Optical Depth (AOD) values were observed during the summer season and minimum AOD occurred in winter with mostly coarse mode particles.

Keywords: Aerosols; Aerosol Optical Depth; Remote Sensing; MODIS

1. Introduction

Atmospheric aerosols are tiny particles or droplets suspended in the atmosphere. They can be composed of various substances, including dust, pollen, soot, smoke, and liquid droplets from ocean spray or industrial emissions. Aerosols can originate from natural sources (like volcanic eruptions, sea spray, and forest fires) or human activities (such as burning fossil fuels, industrial processes, and agriculture). Aerosols influence the Earth's climate in several ways, such as they can reflect sunlight, leading to cooling effects (aerosol radiative forcing) (Stanhill and Cohen, 2001; Che et al., 2005). They also affect cloud formation and properties, which can alter precipitation patterns (Twomey et al., 1984; Hansen et al., 1997). Despite many aerosol studies, the aerosol concentrations and optical properties are one of the largest sources of uncertainty in current assessments and predictions of global climatic change (IPCC, 2007, Hansen et al., 2000). Aerosols also influence air quality and therefore affect human health, and reduce visibility so as to affect traffic. Aerosol optical depth (AOD) is a basic optical parameters of aerosol particles and key factors for the climate change research (Breon et al., 2002).

Aerosol Optical Depth (AOD) is a measure of the extinction of sunlight by aerosols in the atmosphere. It quantifies how much aerosol particles in the air prevent sunlight from reaching the surface. AOD is measured using ground-based instruments like sun photometers, as well as satellite sensors. Satellite data allows for large-scale monitoring of aerosol distribution, composition and effects of weather and climate over vast areas. In particular, satellite remote sensing such as MODIS (Moderate Resolution Imaging Spectroradiometer) is an efficient way to monitor aerosol optical properties. MODIS is on-aboard both the polar orbiting TERRA and AQUA satellites. The MODIS aerosol products, which provide the ability to monitor spatial–temporal characteristics of the global aerosol field, obtain aerosol properties over land (Kaufman et al., 1997) and ocean (Tanre et al., 1997), using seven well calibrated spectral channels (0.47–2.1 μm).

2. Site description and data methodology

The measurements of aerosol optical properties were carried out at Ballari, located in the south eastern part of Karnataka, Ballari is surrounded by hills and is characterized by its rocky terrain (Fig. 1). In Ballari, various sources contribute to aerosol presence in the atmosphere such as mining activities, agricultural practices, industrial emissions,

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vehicle emissions and biomass burning etc. These sources can affect air quality and have implications for health and climate in the region. The mining industry plays a significant role in the local sources of aerosols, along with agriculture.

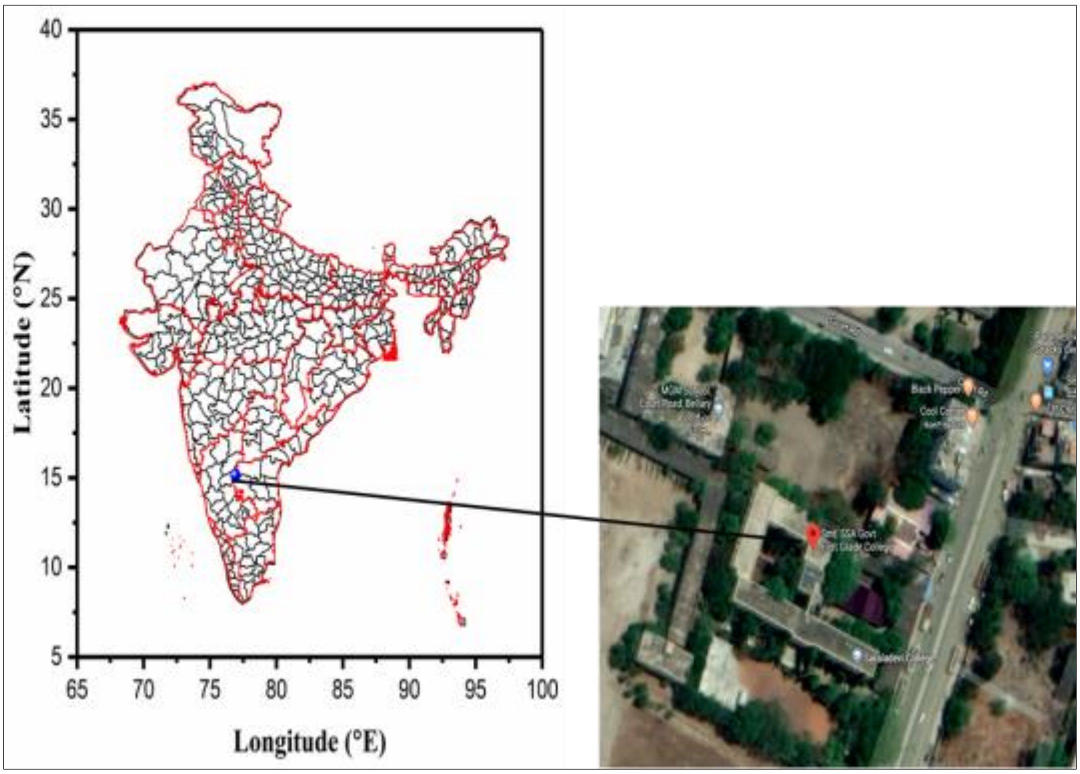

Figure 1 Map of measurement location

The MODIS sensors on board Terra and Aqua satellites (launched December 1999 and May 2002, respectively) have 36 spectral channels providing information on atmospheric, land, and oceanic conditions. Terra crosses the equator southward about 10:30 local solar time (LST), whereas Aqua northward about 13:30 LST. MODIS aerosol products are very useful in detail studies of aerosol distributions. Aerosol retrievals are different over land (Kaufman et al., 1997) from over the oceans, with MODIS aerosol retrievals over land not expected to be as accurate as over the oceans. The percentage error is thus consistently smaller over the oceans than it is over land (Remer et al., 2005). The reliability of this proxy depends on the uniformity of the aerosol size, composition, vertical distribution, but may in many cases be used as a first approximation. To simplify the data handling and analysis and to reduce the variance, pixels with large spatial area are used. The MODIS data are available at different processing levels, level 1.0 (geolocated radiance and brightness temperature), level 2.0 (retrieved geophysical data products) and level 3.0 (gridded points) (King et al., 2003). More detailed information on algorithms for the retrieval of aerosol and cloud parameters is available at http://modis-atmos.gsfc.nasa.gov.

The aerosol data derived from the two MODIS sensors have been used in numerous publications in the last years focusing on a variety of topics, such as the investigation of the regional and global aerosol distribution (Balakrishnaiah et al., 2011; Chin et al., 2004; Ichoku et al., 2004), air pollution monitoring (Engel-Cox et al., 2004; Hutchison et al., 2004), radiative forcing and climate response(Christopher and Zhang, 2004; Vinoj et al., 2004; Yu et al., 2004), aerosol interactions with clouds (Koren et al., 2004; Alam et al.,2010). The data quality is essential for all these applications, while the necessitated accuracy of the retrievals depends on the spatial and temporal resolution.

In this paper, MODIS aerosol products over land are evaluated. The data analysis in this paper uses data from the MODIS sensor aboard the Terra satellite from Collection 5 level 2 MODIS aerosol products, which are produced at a spatial resolution of a 10 km×10 km pixel array. We used AOD data for the period between Jan-2020 and Dec-2023.\

3. Results and discussion

3.1. Monthly variation of AOD

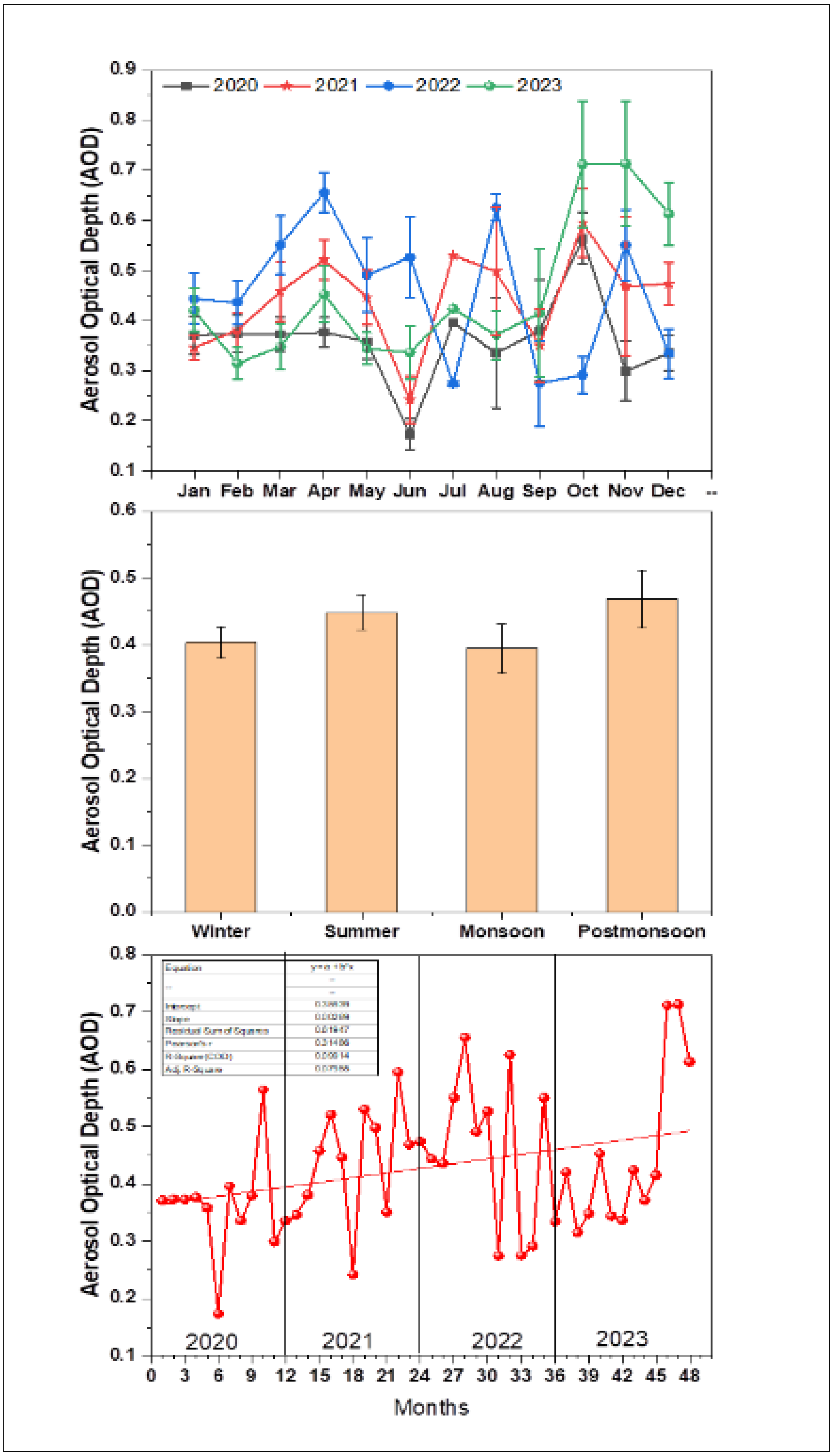

Figure 2 Monthly, seasonal average of AOD over Ballari during 2020-23. Bars indicate standard error about the monthly mean and the average AOD temporal profiles by using MODIS-Terra (D3)

The monthly variation of Aerosol Optical Depth (AOD) can provide insights into seasonal patterns, sources, and the impact of aerosols on climate and air quality. The highest value of the monthly mean AOD at 500 nm (over 4-year period) is 0.45 ± 0.03 (in summer) and the lowest is 0.39 ± 0.04 (in monsoon) (Fig.2). The mean AOD and standard deviation at 550 nm were calculated during the period 2020-2023. On the other hand, high AODs during the summer period could be attributed to increased concentration of continental aerosols due to strong surface winds, which play an important role in lifting the loose soil, which shows a higher frequency for larger AOD values. Also, increased industrial activity can lead to spikes in AOD. Similar trend in AOD during the summer season has previously been reported for Indian subcontinent (Prasad et al., 2004, Balakrishnaiah et al., 2012). In monsoon months rains can significantly reduce AOD as rain helps wash out aerosols. Industrial activities and urban emissions may cause spikes in AOD, particularly in months with increased industrial output or traffic. A Low AOD value during winter months is due to fewer natural dust sources and reduced biomass burning activities. Urban emissions might still contribute to AOD, but overall levels may be lower. In postmonsoon months, AOD may begin to rise again as monsoon effects diminish. Agricultural burning and other activities can contribute to higher levels. The transition from wet to dry seasons can lead to increased dust and smoke from land clearing. Seasonal variations may be influenced more by human activities, leading to spikes during industrial or agricultural activities. We analysed the AOD trends from MODIS D3 data over Ballari regions, generally it is positive. We derive a strong positive trend for MODIS AOD over location.

The frequency distributions of AOD are shown in Fig. 3 respectively. The bin intervals for the AOD at 550nm were set up to 0.10 in this study. It can be seen from Fig.2 that the frequency histograms of AOD showed obvious single peak distributions in all seasons. It is found that the AOD can be better characterized by a log normal distribution (O'Neill et al., 2000) and the results in this study also confirm this point. AOD at Ballari ranged between 0.20-0.80 (Fig. 3), with the most frequent distribution of AOD between 0.20 to 0.60 accounting for 74%.

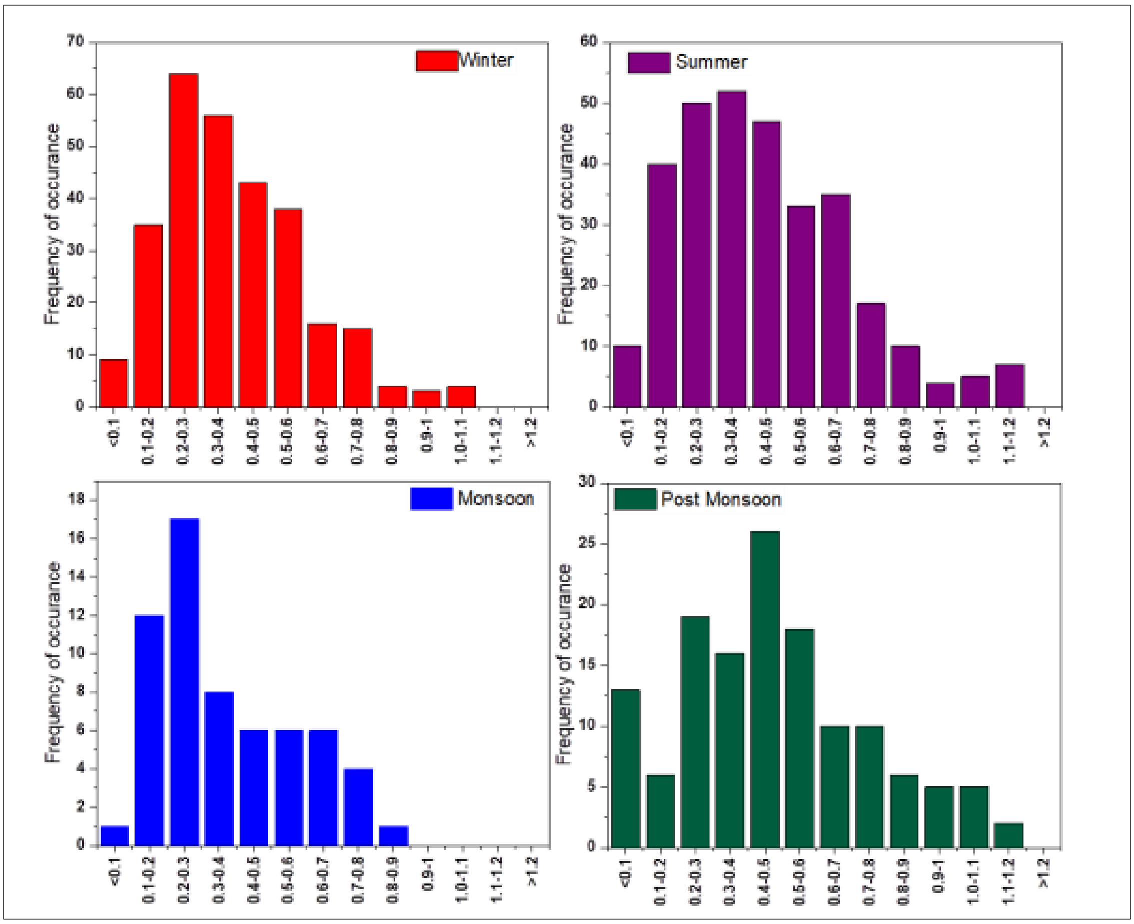

Figure 3 Frequency of occurrence of AOD

4. Conclusion

This paper presents the seasonal, temporal and interannual variability of aerosol optical properties over a semi-arid region over Ballari. The main conclusions drawn from our study are summarized as follows:

- The aerosol optical depth showed large annual variation with high values during summer and low values during monsoon season. Coarse-mode and growth in fine-mode waters soluble aerosols due to higher ambient RH result in high AOD in the summer, while during the winter the AOD is slightly lower, which is mostly associated with fine-mode particles. Thus, it is observed that anthropogenic sources dominate the aerosol distribution, which could get modulated by the presence of natural aerosols.
- The frequency distribution of AOD in all seasons reveals a great dispersion of the values thus denoting variability in the aerosol-size distribution. The frequency distribution reveals that dust is the major contributor to the optical depth

Compliance with ethical standards

Acknowledgments

We would like to say special thanks to the Department of PG studies in Physics, SSA Government First Grade College (Autonomous), Ballari, for providing laboratory facilities.

Disclosure of conflict of interest

The authours delcare that they have no known competing financial interests or personal relationships influenced by this work.

Authors contribution statement

Kuncham Narasimhulu*-investigation, data interpretation, software, writing original draft, conceptualization, figures and tables preparation , formal analysis and editing Gmail - drsimhasku@gmail.com **Shalini V** - software, figures, and tables preparation, formal analysis and editing Gmail - shalini.gadag@gmail.com

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