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Wintertime variation of PM_{10}, $PM_{2.5}$, Black Carbon, and Aerosol Optical Depth over Varanasi

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Abstract

Black Carbon (BC) and Particulate Matter (PM_{10} and $PM_{2.5}$) are measured over Varanasi during the winter season. They are the most crucial atmospheric aerosols that play an important role in Earth's radiation budget by absorbing solar and terrestrial radiation. Aerosol Optical Depth (AOD) is the measure of extinction of incoming solar radiation by air particles distributed in a vertical column of the atmosphere. The influence of the atmospheric boundary layer (ABL) is observed on the diurnal variation of BC, PM_{10}, and $PM_{2.5}$. The concentration of these parameters was high during morning and evening hours when ABL is lying near the ground. Maximum and minimum concentrations of PM_{10} and $PM_{2.5}$ are found to be in November and February. Burning firecrackers during Diwali in November could be the reason for high aerosol loading. Higher BC concentration is measured in January due to increased anthropogenic activities and biomass burning. AOD at 500 nm is found to be higher in December and lower in February. The higher value of AOD at a shorter wavelength suggests the dominance of fine mode particles.

1. Introduction

Atmospheric Aerosols such as Black Carbon (BC), $PM_{2.5}$, and PM_{10}, have significantly increased in growing countries that play an essential part in the Earth's radiation budget [1]. Black carbon (BC) is among the crucial elements of atmospheric particulate matter that is emitted into the atmosphere as a result of biomass burning and incomplete combustion of fossil fuels [2] whereas Particulate Matters ($PM_{2.5}$ and PM_{10}) originate in the atmosphere as a result of complicated chemical processes, such as Sulphur dioxide and nitrogen oxides, or are released directly from a source, such as building sites, unpaved roads, fields. Indo- Gangetic Basin (IGB) is one of the key regions of the country that is extensively affected by the various types of aerosols [3-5]. IGB has frequently dense haze throughout the winter due to weak convection and shallow atmospheric boundary layer (ABL) [6]. In addition to being a regional issue, air pollution concentrations also have consequences on the global climate system. Daily variability in the concentration of aerosols is influenced by the height of ABL [7-8]. The attenuation of incoming solar radiation by air particles dispersed in a vertical column of the atmosphere can also be assessed by the quantity known as aerosol optical depth (AOD), which is used to assess PM concentrations [9]. In the present study, variations of BC, $PM_{2.5}$, PM_{10}, and AOD are analyzed over Varanasi during the winter season from November 2021 to February 2022.

2. Data and Methodology

Varanasi (25.31º N, 82.97º E) is a spiritual city in the IGB's densely populated central region. It is notable for its multiple sources of aerosol deposition, the majority of which are generated by the combustion of biomass and the re-suspension of road dust [10]. Varanasi has a humid subtropical climate with significant temperature differences between summer and winter [11]. November to February is considered the winter months. A seven wavelength Aethalometer (AE33, Magee Scientific, USA) for measurement of BC concentration and MICROTOPS-II Sunphotometer (Sunlight Company Limited, USA) for measuring AOD (at 380, 440, 500, 675, and 870 nm) were used during this study period. Concentrations of $PM_{2.5}$ and PM_{10} were taken from the IESD-BHU sampling site installed by the UPPCB. The single-level ERA5 was used to download the ABL reanalysis data. The hourly AOD data were collected on clear sky days at the Department of Physics, BHU, Varanasi. The Aethalometer for measuring BC at 880 nm was installed on the Department's terrace at a height of roughly 12 m agl.

3. Result and Discussion

For the current analysis, four months of the year i.e. November, December, January, and February are considered a winter season. Figure 1 represents the diurnal variation of the atmospheric boundary layer over Varanasi, obtained from the ERA5 reanalysis data during the study period. The ABL height is significantly higher in February. ABL height is quite low before sunrise and afternoon. ABL is lying near the ground during November. The diurnal variation of PM_{10}, $PM_{2.5}$, and BC is shown in Figures 2, 3, and 4 respectively during the winter season. The highest and lowest mean concentrations of PM_{10} were found to be 151±33 and

77±18 μg/m^3 during November and February respectively (figure 2). Similarly, the highest and lowest mean concentrations of $PM_{2.5}$ were found to be 96±25 and 45±13 μg/m^3 during November and February respectively (figure 3). The average concentrations of PM_{10} and $PM_{2.5}$ throughout the winter are observed to be 102.3±20.6 and 66.4±15.6 μg/m^3, respectively. While in the winter of 2019–20, these concentrations were reported as 224±70.8 and 156.1±59.3 μg/m^3 respectively [12]. Monthly mean concentrations of BC are found to be maximum in January (06±1.93 μg/m^3) and minimum in December (3.7±1.1 μg/m^3) (figure 4). The same pattern (two minima) in diurnal variation of all three aerosols index (PM_{10}, $PM_{2.5}$, and BC) occurs throughout all over the months, this could be a reason for the dynamics of ABL [7]. Figure 5 represents the variation of AOD at five different wavelengths (380, 440, 500, 675, and 870 nm). It depicts the relatively higher value of AOD at 500 nm in December (1.13±0.36) followed by November (1.1±0.36), January (0.91±0.29), and the lowest in February (0.73±0.33). The maximum and minimum value of AOD is found to be at a shorter wavelength which shows the presence of high concentrations of fine particles and at a longer wavelength which depicts the presence of coarse mode particles respectively [13].

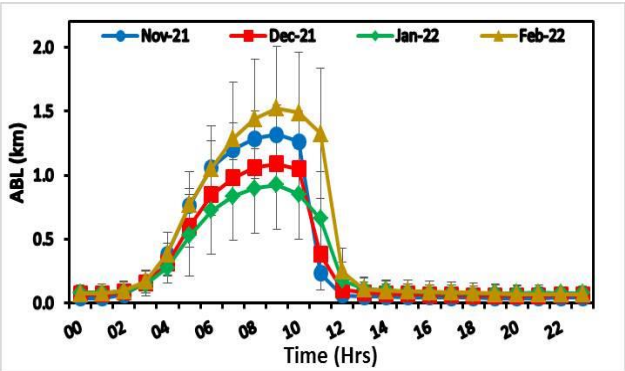

Figure 1. Diurnal variation of Atmospheric Boundary Layer during the study period from November 2021 to February 2022.

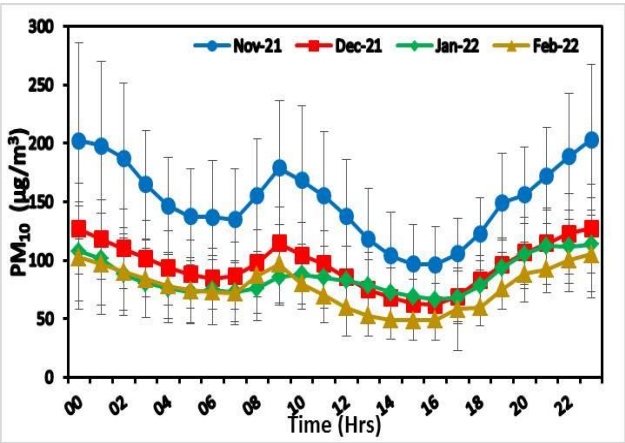

Figure 2. Diurnal variation of concentrations of PM_{10} during the study period from November 2021 to February 2022.

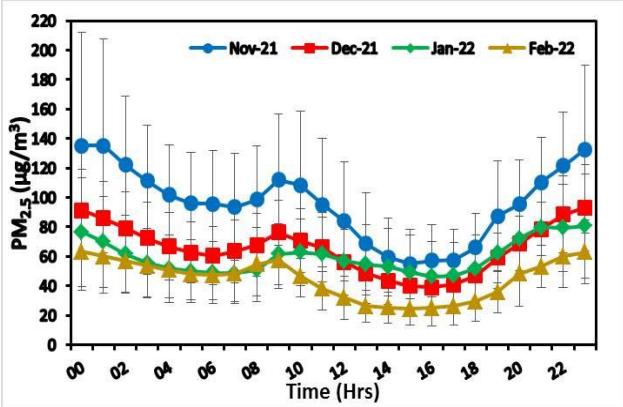

Figure 3. Diurnal variation of concentrations of $PM_{2.5}$ during the study period from November 2021 to February 2022.

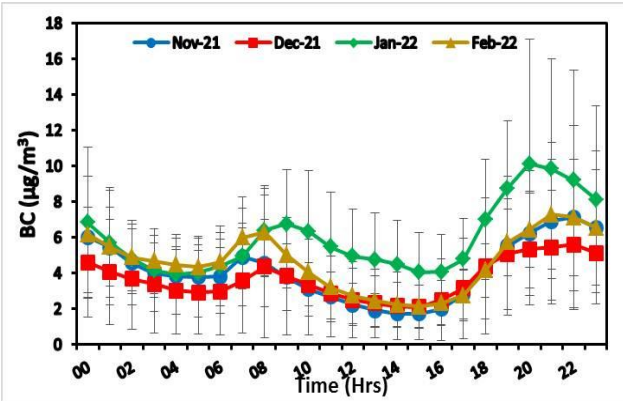

Figure 4. Diurnal variation of concentrations of BC during the study period from November 2021 to February 2022.

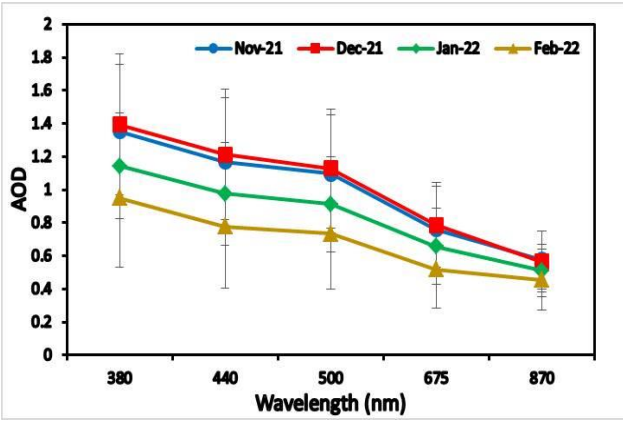

Figure 5. Variation of AOD at five different wavelengths during the study period from November 2021 to February 2022.

4. Conclusion

The current study demonstrates the fluctuation in PM_{10}, $PM_{2.5}$, BC, and AOD with the impact of ABL during the winter season over Varanasi. The highest concentrations of all atmospheric aerosols are seen in the early morning and late evening when the ABL height is at its lowest. The increased concentrations of PM_{10} and $PM_{2.5}$ with

higher AOD_{870nm} observed in November indicate the predominance of coarse mode particles. The concentration of BC is found to be higher in January which shows the dominance of biomass burning particles.

5. Acknowledgements

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