***Original Research Article***

# Aerosol Black Carbon measurement at High altitude Western Ghats location of Ooty, Tami Nadu


## Abstract

The aerosol black carbon (BC) are particles formed from the incomplete combustion of fossil fuel and biomass combustion which was collected from high altitude location in Western Ghats, Ooty, Tamil Nadu using Aethalometer Instrument AE 31 model during 2017. The monthly averaged BC concentration shows highest value of 1.88 ± 0.44 µg $m^{-3}$ during April with the annual mean of 0.83 ± 0.20 µg $m^{-3}$. The diurnal variation shows higher seasonality especially in winter and summer. The aerosol optical depth is derived from MERRA 2 model and it is in line with BC concentration.


Comment [I1]: Put optical depth values here


***Keywords*:** Black carbon, Aethalometer, Aerosol optical depth, Aerosol, MERRA-2


## 1. Introduction

Aerosols are tiny particulate air pollutants suspended in the atmosphere have a much bigger impact on the earth and are ubiquitous.

Aerosols have sizes ranging from 0.001 to 10 µm (Haywood, 2016). Among them, BC has been more attention in recent times. The major sources of BC are forest fires, wood burning, vehicular emission and industries, which are of anthropogenic origin (Ramachandran and Rajesh, 2007). In global, BC emission from anthropogenic activities are 7500 Gg/yr (Bond *et al.*, 2013). It is well known that aerosols affect the climate through scattering and absorptive properties, which are depending on the type of particle, their size and altitude where they found (Mogo *et al.*, 2005). For example, sulphate aerosols scatters the solar radiation results in negative radiative forcing responsible for cooling of Earth, whereas BC has efficient light absorbing characteristics, that leads to warming effect. Freshly formed BC aerosols are hydrophobic in nature and their residence time in the atmosphere varies between few days to week, whereas the aged particles are changed to hygroscopic due to mixing of other species during atmospheric process (Rajeshkumar *et al.*, 2019). To understand the effect of atmospheric transport and anthropogenic source, diurnal BC concentration is essential (Bhaskar *et al.*, 2018).

Aerosol Optical Depth is the measure of aerosols distributed over the vertical column of the atmosphere by which they can block sunlight by absorbing or scattering it and it is good indicator of biomass burning (Jethva and Torres, 2011). As black carbon aerosol is a primary pollutant particulate matter, its absorption coefficient is important to calculate the direct radiative forcing. In previous studies, Udayasoorian *et al.* (2014) reported the dominance of fossil fuel and biomass burning in the study period especially during summer. Another study, Kompalli *et al.* (2018) confirms the highest concentration of BC during summer attributed to winds mainly from south and south directions and found the possibilities of *ex-situ* particles and gaseous species in the study site. Based on the prelude, current study was taken up to understand the daily, monthly and seasonal variability in the study site.

## 2. Materials and Methods

### 2.1. Study site description

The "Ooty" observational site belongs to Nilgiris biosphere (Blue Mountains), is situated in one of the highest mountainous ranges of Western Ghats of Southern India (fig. 1). The observational site is known for its own microclimatic condition as well as considered as rural (Clean) site and is located at 2520 m a.m.s.l.

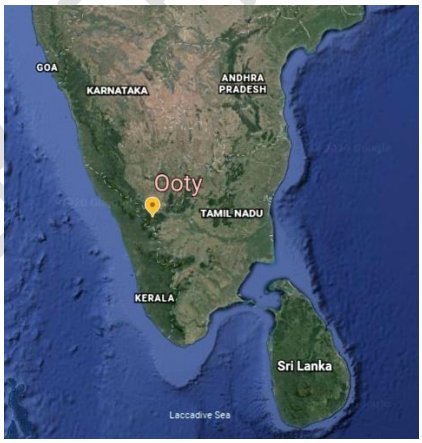


**Fig.1. Study site located at high altitude location in Southern part of Western Ghats (11°25'27"N, 76°43'27"E, 2520 m a.m.s.l)**

**Courtesy: Google Earth**

The study site is one of the main tourist sites in southern India because of the elevation results in a much cooler and wetter climate than the surrounding plains. The only local source of

pollution is wood burning for domestic purpose, tea industry and vehicular traffic during day time particularly in winter and summer season. Around 3.269 million people visited Ooty in 2017. Dense forests, lofty mountains, an amazing variety of flora and fauna extensive tea and coffee plantation and sprawling grasslands characterize the location. The Nilgiris is India's first biosphere reserve and it has been declared as world heritage site by UNESCO in 2012 (Chitale *et al.*, 2015; DUBEY, 2017).

**2.2. Black carbon measurement**

BC mass concentrations were measured daily with a temporal resolution of 5 min using a seven-channel Aethalometer (Model AE-31, Magee Scientific, USA) for a period of one year (2017). As the particles deposited on the quartz fiber filter paper as spot, the change in attenuation were observed at seven different wavelength (370, 470, 520, 590, 660, 880 and 950 nm). As the instrument has been factory calibrated with a flow rate of 4 LPM, the light attenuation absorption coefficient is converted into BC mass concentration (Yang *et al.*, 2009).

The true BC mass concentration ($M_{BC}$) ~~is~~ was calculated as

$$M_{BC} = M^{*}_{BC}\left[\frac{P_0 T}{P T_0}\right]^{-1}$$

Where, $M^{*}_{BC}$ is the Raw mass concentration of BC measured at ambient condition, $P_0$ and P is the Standard pressure and Ambient pressure, $T_0$ and T is the Standard temperature and Ambient temperature.

**2.3. Aerosol optical Depth measurement derived from MERRA-2 model data**

The second Modern-Era Retrospective analysis for Research and Applications (MERRA-2), NASA's global Earth system model, was used to study the aerosol components at 0.5° × 0.626° resolution from Giovanni (Sun *et al.*, 2019). The MERRA 2 timely averaged data at 550 nm for the period of one year (2017) was downloaded from M2TINXAER 5.12.4 from MDISC, Goddard Earth Sciences (GES) Data and Information Services Center (DISC) in NetCDF format. Using GIS tool, the data are imported as a raster layer and the values are extracted for the study site co-ordinates.

**3. Results and Discussion**

**3.1. Monthly variation of BC concentration**

The averaged monthly variation of Black carbon concentration measured in 2017 are shown in fig. 2. The highest concentration was recorded during April month, while the lowest during September. The annual mean BC concentration during 2017 was 0.83 ± 0.20 µg $m^{-3}$. Overall, the BC concentration increases gradually during January and reached the highest in April. Then, the concentration suddenly falls to the lowest and again it increases. It might be attributed to the local meteorological conditions and also the rainy season occurred in the study site from June to September, 2017. The decrease in the BC aerosol might be due to the scavenging effect of precipitation resulted in the lower concentration. Likewise, from March to May, the temperature was high when compared with rest of the other months. This may lead to uplift of BC aerosols from the local source. In previous study, the mean concentration of BC in the study site was 0.61 µg $m^{-3}$ (Udayasoorian *et al.*, 2014). Whereas, other sites in Southern India like Madurai and Agartala has mean BC concentration of 1.62 and 17.8 µg $m^{-3}$, respectively (Rajeshkumar *et al.*, 2019; Guha *et al.*, 2014).

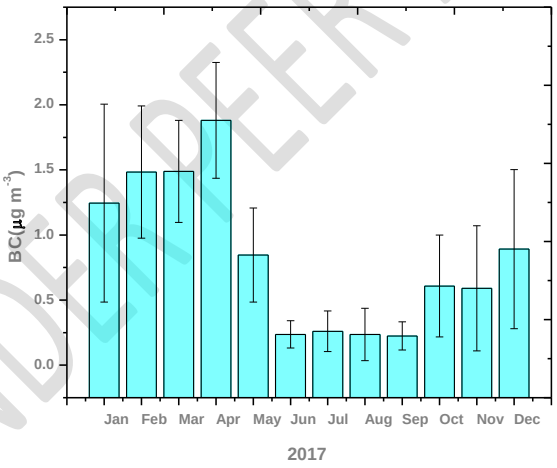


**Fig. 2. Monthly variation of BC aerosol during 2017**

**4.2. Diurnal variation of BC aerosol**

The seasonally averaged diurnal variation of BC aerosol measured for the period of 2017 are shown in fig. 3. The BC concentrations are divided in four seasons namely, winter (January-February), summer (March-May), monsoon (June-September) and post monsoon (October-December). The BC concentration gradually increases from 00:00 (local time) to 23:00 and has highest peak (1.6 -1.9 µg $m^{-3}$) in (17:00 to 22:00) uniformly in all seasons (fig. 3). It indicates the aerosols are transported from the local source emitted during daytime and reaches the study site in evening. This shows that the wind play a major role in transferring of pollutants from the source region to the study site. The results are in accordance with previous study (Udayasoorian *et al.*, 2014) whereas, Bhaskar *et al.* (2018) and Kant *et al.*, (2020) observed two peaks at morning and evening in Madurai and Dehradun, respectively.

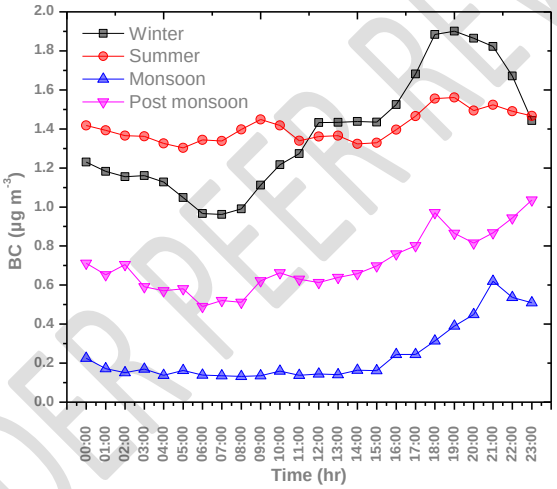


**Fig. 3. Diurnal variation of BC during 2017**

**4.3. Aerosol optical depth (AOD) of BC aerosol**

The Aerosol optical depth data are retrieved from MEERA 2 model at 550nm on monthly basis are shown in fig. 4. As the aerosol loading increases, BC aerosol concentration also increases. The aerosol optical depth data shows similar pattern with monthly averaged BC concentration (fig. 2) with the highest concentration during Aapril and lowest during the ~~momsoon~~ monsoon season of June to September, 2017. The mean AOD value of 2017 was 0.29. As mentioned above, the particles are driven by wind from different source region to the study

site. Pathak *et al.* (2015) and Gogoi *et al.* (2011) reported the AOD value of 0.52 and 0.071 in Shillong and Hanle, respectively.

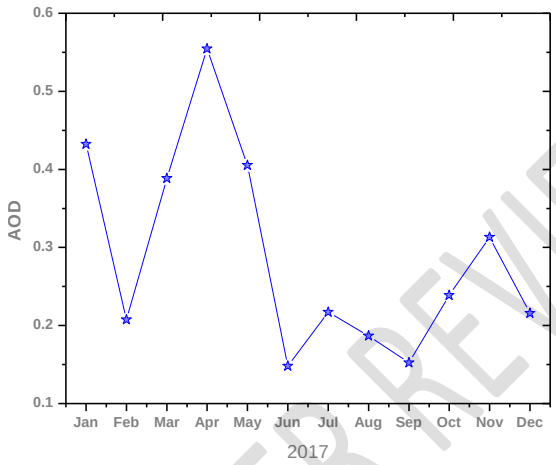


**Fig. 4. Aerosol optical depth in the study site during 2017**

## 5. Conclusion

The mean mass concentration of black carbon and aerosol optical depth during the study period was 0.83 ± 0.20 µg $m^{-3}$ and 0.29, respectively. Even though the observation site is clean, the BC concentration showed daily, monthly and seasonal variability. It confirms the influence of meteorological parameters on BC concentration during the study site. In future, studies on influence of meteorological conditions, source and origin in detail is essential for better understanding of BC concentration in the study site. As, BC is the second largest contributor to radiative forcing, it is important to study the seasonal and diurnal variation and characteristic properties and mixing species of BC aerosol in the atmospheric during long range transport continuously.

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