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Studies on the sources of aerosols during winter over the high-altitude region, Ooty

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Abstract
The incomplete combustion of carbonaceous fuels generates the Black carbon aerosol particle, which concentration has measured by using the Aethalometer (AE-31 model) at high altitude region, Ooty. This study has analyzed the diurnal and monthly variation of Delta-C values for the Winter 2021. The average Delta-C value for the January, February was 0.003 and 0.04, respectively that indicates the relative dominance of wood burning smoke particles. In January the Delta-C values were shows negative during the early morning (03:00 LT), morning hours (06:00 to 08:00 LT) and afternoon hours (13:00 to 15:00 LT). The positive values indicate that the presence of wood burn smoke, during February the most of the diurnal hours shows positive value except the morning hour (06:00 LT) and afternoon hour (13:00 LT). The results show that the wood burning smoke dominated diurnally over the Winter. The aromatic organic compounds, smoke and Fossil fuel & Biomass burning based particles were contributing at equal percentage (20%) over the study period. The contribution of Hematite mineral dust was 21% during the entire Winter.

Keywords: Aethalometer, delta-c, wood burning smoke, wavelength based source apportionment

1. Introduction
Aerosols are ubiquitous airborne particles generated from both the natural and anthropogenic events (Tiwari *et al.* 2014) [8]. Black carbon (BC) (also known as soot) was emitted from the vehicular exhaust, biomass burning, and industrial emissions (Ramachandran and Rajesh, 2017) [6]. The Delta-C calculated from the Aethalometer derived concentration has been noted as an indicator for wood burning particles over the other sources of particles contribution to the aerosols (Wang *et al*., 2011). Different source coating over the aerosols results in absorption of different wavelength (Bond and Bergstrom, 2006) [1]. The organic aerosol species strongly absorbs the UV wavelength, hematite mineral dust (form of iron oxides) absorb visible light at wavelengths < 600 nm (Yang *et al*., 2009) [9]. In this paper we present the results for the Delta-C over a high-altitude region over the period of Winter (January to February 2021) and their diurnal and monthly variability, and contribution of different sources for the aerosol concentration over the study period.

2. Materials and Methods
2.1.1. Site description
The study site "Ooty" was located at 2520 m AMSL (11.42 ºN, 76.72 ºE) near to the Doddabetta peak belongs to the Western Ghats (Fig.1). This site has been undisturbed by the human activities, attributed with dense tropical forest, grasslands, plantations and mountain coverage.

Fig 1: Study site located at Latitude - 11.42ºN, Longitude - 76.72ºE, Altitude 2520 AMSL

2.2. Instrumental Measurement

Seven-Channel Aethalometer (AE-31 Magee Scientific Model) was measures the Black Carbon mass concentrations at the interval of five minutes with the flow rate of 4 LPM. Aethalometer measures the optical attenuation at seven different wavelengths *i.e.*, 370, 470, 520, 590, 660, 880 and 950 nm. The light absorption measured at 880nm wavelength represents the BC concentration (Kowsalya *et al*., 2020). The BC concentration is measured by the variation of optical transmittance and the optical attenuation of the beam that has been transmitted through the particles deposited quartz filter paper (Hansen, 2005) [3].

The BC concentration ([BC]measured) measured by Aethalometer is calculated based upon the standard mass flow rate, the actual/corrected BC concentration ([BC]true) calculated by;

$$BC_{true} = BC_{measured}\left[\frac{P_0 T}{P T_0}\right]^{-1}$$

Where

$BC_{measured}$ - Raw mass concentration of measured BC at ambient condition

P_0 and T_0 - Standard pressure and Temperature

P and T - Ambient pressure and temperature

The calculation of Delta-C noted as an indicator of wood burning particles, but it does not denote the direct quantitative measurement (Rajeshkumar *et al*., 2019) [5].

$$\text{Delta C} = BC_{(370nm)} - BC_{(880nm)}$$

3. Results and Discussion

3.1. Diurnal variations of Delta-C

The Delta-C values shows a significant variation over the time period (Fig. 2). During the January the Delta-C values were shows negative during the early morning (03:00 LT), morning hours (06:00 to 08:00 LT) when the rise of sun and gradual increase in temperature and afternoon hours (13:00 to 15:00 LT) when the temperature is very high. The positive values indicate that the presence of wood burn smoke. Whereas, during the February the most of the diurnal hours shows positive value except the morning hour (06:00 LT) and afternoon hour (13:00 LT). This indicates the wood burning smoke dominated diurnally over the February month. The negative values indicate the no effect of wood burning and it also might due to desorption of UV absorbing semi-volatile organic species from the filter between consecutive samples. During the morning hours and noon hours associated with the increasing temperature leads to the widening of atmospheric boundary layer which allows more loading of pollutants. Hence the concentration and Delta-C value shows higher during those hours. After the sunset the surface inversion layer has form and trap the carbonaceous pollutants that was reason for the positive Delta-C values during the evening hours. This finding was similar to the results of Rajeshkumar *et al*. (2019) [5] and Wang *et al*. (2011).

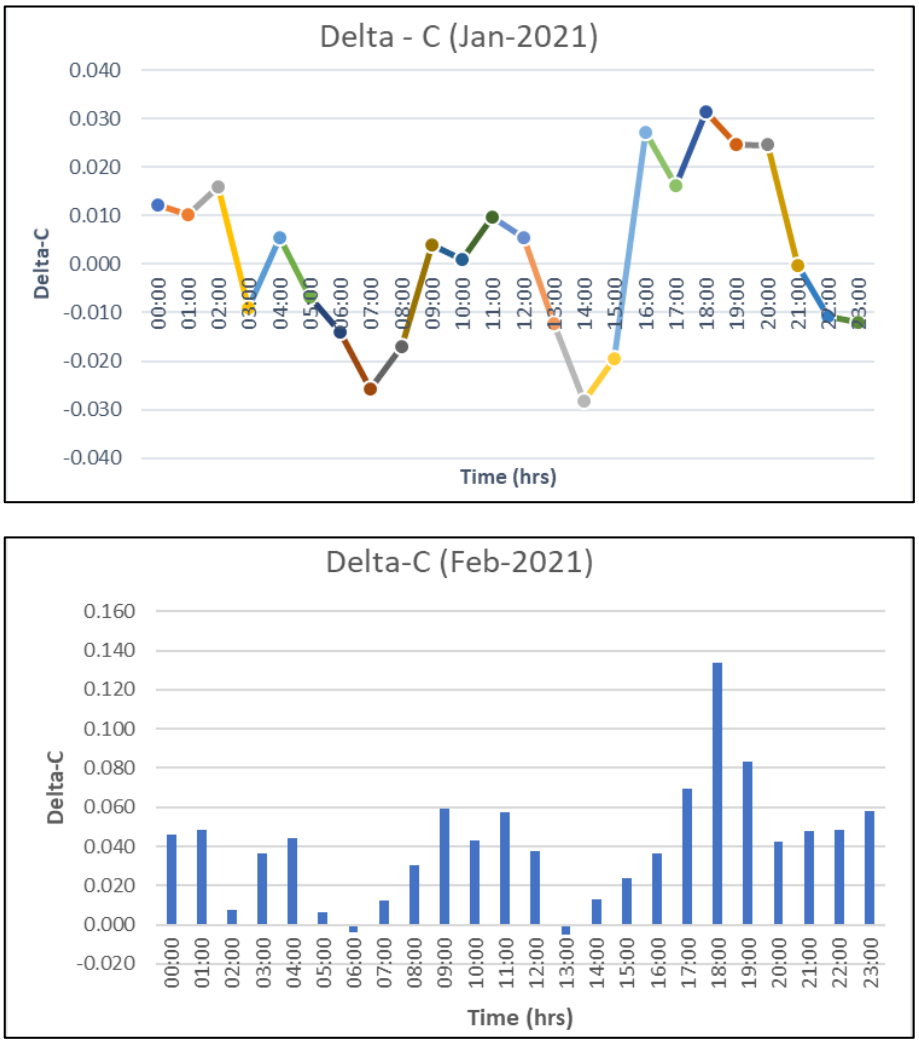


Fig 2: Diurnal variation of Delta-C during Winter-2021

3.2. Monthly Variation of Delta-C

During the entire winter season, the January and February noted 13 days of negative Delta-C values. The values vary with each month (Fig. 3). The negative values during the January and February shows the relative dominance of other organic species and fossil fuel burned particles. The values are also higher than the February Delta-C values. The Delta-C values during January are found to be negative in day and night hours indicating the dominance of fossil fuel-based BC, while during February, positive Delta-C during day and night time corresponded with an increase in anthropogenic activities and residential wood burning emissions. The mean Delta-C value for the January was 0.003, for the February was 0.04 that indicates the relative dominance of wood burning smoke particles during the February than the January. Collectively, the winter season attributed with the wood burning particles. This result was similar with the findings of Sarkar *et al*. (2015) [7] and Gupta *et al*. (2017) [2].

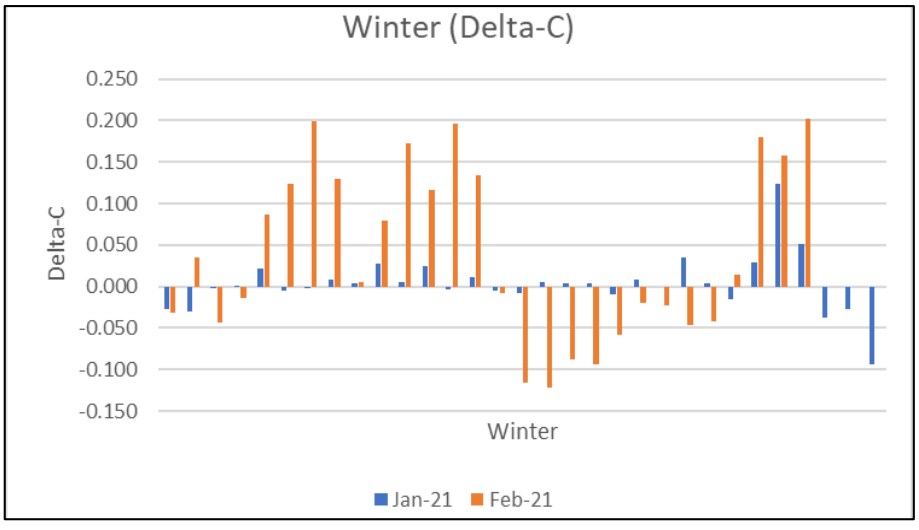
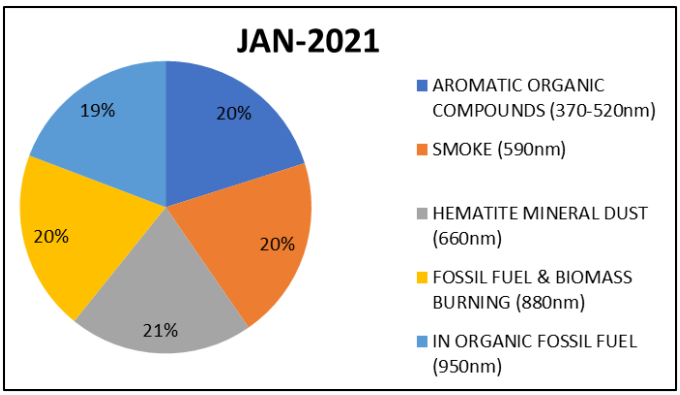


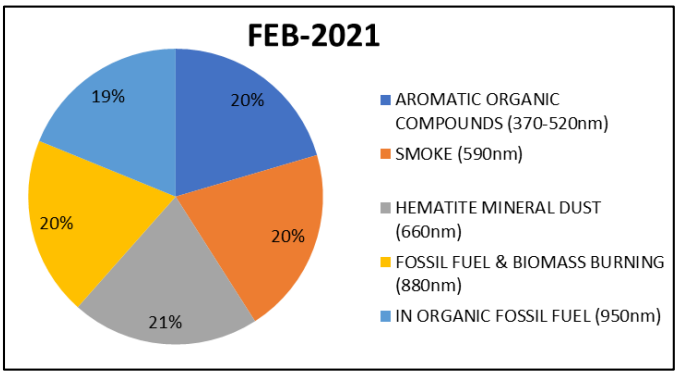
Fig 3: Monthly variation of Delta-C

3.3. Contribution of different sources to Aerosol

The sources like tobacco smoke, hematite mineral dusts and inorganic fossil fuels are recorded at different wavelengths 590, 660nm and 950 nm, respectively using the Aethalometer. These are the several sources other than fossil fuel and biomass burning which has contributed to the total BC concentration**.** The wavelengths-based source apportionment has been taken into the account as mentioned in the Aethalometer manual (Hansen, 2005) [3]. The percentage distribution of BC from different sources during January and February 2021 were noted separately (Fig. 4a & b) and considered for entire season collectively. The aromatic organic compounds, smoke and Fossil fuel & Biomass burning based particles were contributing at equal percentage (20%) over the study period. Notably, the contribution Hematite mineral dust was higher than the other sources with 21%. This result was in contrast the findings of Rajeshkumar *et al.* (2019) [5] in Madurai where the Smoke dominated the other sources of aerosols.



A.



B.

Fig 4: Contribution of different sources to Aerosols a) January 2021 b) February 2021

4. Conclusion

The present study addresses the diurnal and monthly variation of the Delta-C values during the entire winter season and the percentage distribution of different sources of aerosols at the high-altitude region, Ooty. The results of this study are;

- The mean Delta-C value for the January - 0.003, February - 0.04 that indicates the relative dominance of wood burning smoke particles during the February.
- The winter season attributed with the wood burning particles.
- The aromatic organic compounds, smoke and Fossil fuel & Biomass burning based particles were contributing at equal percentage (20%) over the study period.
- The contribution of Hematite mineral dust was 21% during the entire Winter.

5. Acknowledgement

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