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Study on Variability of black carbon concentration, biomass burning and fossil fuel emission over New Delhi

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Abstract:
In the present time the mass concentration of Black carbon aerosol has increased results to fog in the winter season and causes atmospheric heating and contributes to global warming. So taking all this in consideration the variability of Black carbon (BC) mass concentration, biomass burning and fossil fuel emission is investigated over New Delhi with the help of the instrument Aethalometer (AE- 33) installed at India meteorological department (IMD) New Delhi. So far the continuous observation for the winter period have been collected and analyzed for four months (October to January). Mass concentration of black carbon aerosol in the New Delhi region was found to be increased in first three months (Oct, Nov, Dec 2017) and decrease in the January 2018. We got the extensively high value of BC concentration in the month of December i.e. 25 μg/m^3 because of the lowering of temperature which leads to the lower boundary layer and Due to less dispersion of air mass and constant emission of pollutants from various sources. While the concentration of the biomass burning is seen increased in the month of October to November from 2.6 μg/m^3 to 4.6 μg/m^3.The monthly mean concentration of fossil fuel emission shows a highest value in the month of December to 21 μg/m^3 and lowest value in October to 11 μg/m^3.The mass concentration of black carbon, biomass burning and fossil fuel emission concentration was higher in early morning hours and late night hours, due the increase of heavy load vehicles in to the cities and lowering of atmospheric boundary layer. Along with this the meteorological parameters (rainfall, wind speed and direction) also taken in consideration as they are the major influencing factors. There is more research work to be done for the Black Carbon, Biomass burning sources estimation and an endeavor was being planned to explore more over New Delhi region.

Keywords: black carbon concentration, biomass burning, and fossil fuel emission

1. Introduction

The Black carbon (BC) is an important anthropogenic component of aerosol system, which plays an unique and significant role in the climate system of earth and at present is one of major area for research for climate change and impacts related to the studies of health assessment. It is an by-product of incomplete burning of biomass, cooking with solid fuels, diesel and by the Industrial, vehicular and other anthropogenic activities. As it has strong absorbing capabilities and act as dominant aerosol absorber over visible solar radiation over a wide wavelength range in the atmosphere it affects the regional and global climate through heating(M. Shiraiwa, 2010)(JAY PANDEY*, 2013).

The optical and radiative nature of Black carbon makes it different from other types of aerosols and having the optical nature the black carbon absorbs the solar radiations which results into the extinction of sunlight(JAY PANDEY*, 2013),Its photo-absorption is increased by the in-house mingling of BC with volatile compounds (M. Shiraiwa, 2010). It has a life span of few days to week and removed from the atmosphere via precipitation and interaction with the surfaces and with this it is found far from the source location having concentration less than that of the source location. In the study it is shown that BC may be considered as the second most significant component of global warming after CO_2 with reference to direct forcing because of its warming effect exceeded CH_4(Jacobson, 2001).

It affects the radiation balance and the atmosphere by its light absorbing and scattering particles component, which warms and cools the atmosphere by absorbing and reflecting the solar radiation. (Kirchstetter, 2004). Black carbon is dark in colour and warms the earth in two ways, when it is in the air the particles absorbs sunlight and generate heat in the atmosphere, affects the formation of clouds and rain patterns and when it is over the snow and ice, the solar radiations coming is being absorbed instead of reflected back into the atmosphere this again generates heat and increases melting. And as carbon dioxide causes changes in the climate, studies suggest that black carbon contributes to the acceleration of melting sea ice in the Arctic.

The source of emission in the urban areas is mainly through the traffic and industries and in the rural areas is mainly through the wood burning, coal, agriculture fires, and fossil fuels. The biomass burning is also in concern in today's urban environment as the biomass burning relates to the crop burning, forest fire and during the winter season use of woods, coals used for heating and other purposes, is transported to the urban areas and affects the local weather conditions but the contribution of wood burning in the environment is very limited as there is difficulty in obtaining the data of consumption of wood, as it is depends upon the wood material and on the combustion conditions(temperature, biofuel's water content) (Evangelia Diapouli 1, 2017)

The particulate air pollution containing the black carbon caused the adverse health effects Janssen et.al., 2011,2012) because of its submicron range in size it is easily inhaled and Over time exposure to the wood smoke affects the lung and cardiovascular functionalilies (Evangelia Diapouli 1, 2017)

Reduction of air pollution is today's primary need, which should be taken at the local, national and global scale, and it is also essential to understand the source apportionment of pollutants and its degree of contribution to the Iocation (L. Drinovec1, 2015). The optical methods used for the measurement of the BC concentrations and the measurement is done using the instrument Aethalometer (AE-33) and transmitting the light over the filter laden tape containing the sample.
Considering all these issue the Environment Monitoring and Research Centre(EMRC) of India, Department of meteorology established a network of Aethalometer (Magee scientific AE-33) for continuous monitoring of Black Carbon across different part of the country. In the present study data has been collected for New Delhi station from above mentioned networks of IMD for the period 01 October 2017 to 31 January 2018. This data has been analyzed for time series, diurnal pattern, absorption coefficient determination and source apportionment study.

2. Instrument and Methodology

<u>Instrument and Methodology</u>

Fig 1: Black Carbon measurement Aethalometer (Magee Scientific, AE-33)

To measure the Black Carbon concentration and Biomass Burning an instrument AE-33 Aethalometer (Magee Scientific)was used. The instrument measures concentration over the distinct spectral regions (370, 470, 520, 590, 660, 880, and 950 nm). The black carbon (BC) mass concentration is calculated at 880 nm Using the Mass absorption cross section 7.77 m^2/g. At this wavelength (880 nm) other aerosol not absorbs much, the absorption is attributed to BC alone. The instrument pumps the surrounding air through the tube placed 20 m above the ground with a flow rate and time base of 2 LPM and 60 Second respectively. The sample is collected over the filter tape through which a beam of light is passed and a unloaded portion over a filter tape act as a reference area, these two sample spots are obtained from the same input stream over different rates of accumulation (2:1) of the sample, further these two results are combined mathematically and the attenuated light is measured which is proportional to the amount of deposited BC on the filter tape. The data is stored to the internal memory at each time base period and it may further recovered through the external storage.

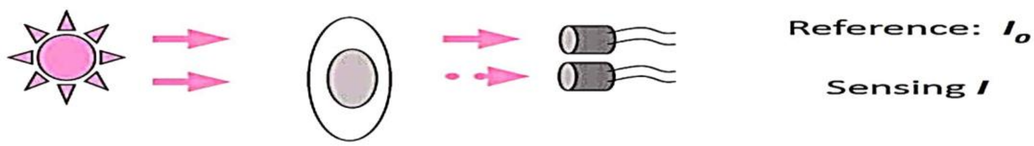

Fig 2: Absorption phenomenon showing the transmission of light through the filter tape containing the sample and through an unloaded part (spot) acting as the reference area.

Front view, open door

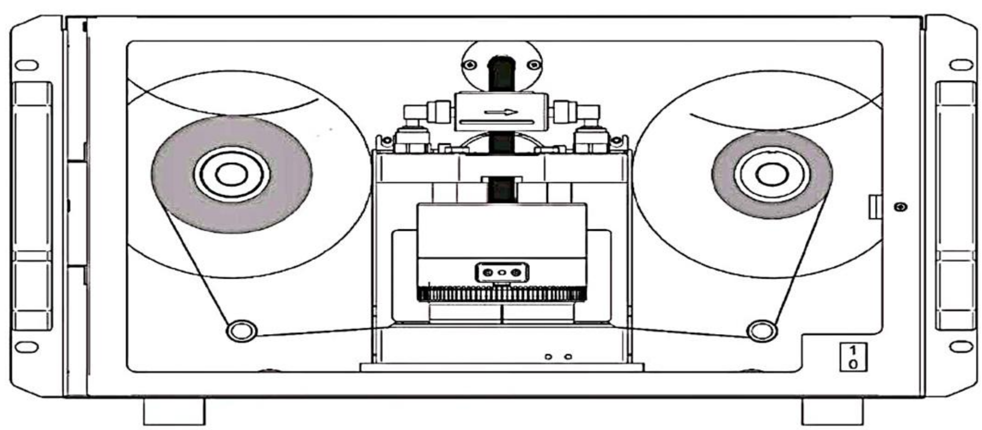

Fig 3: Front view of the Aethalometer showing the filter tape on which the sample is loaded through which the transmission of light is passed and measured

Basic Calculations:

Optical attenuation:	$ATN = -100 * \ln(I/I_0)$	I_0 = reference signal; I = spot signal
Flow:	$F_{in} = F_{out} * (1 - \zeta)$	F_{out} = measured flow; ζ = leakage factor
Attenuation coefficient:	$b_{atn} = \frac{S*(\Delta ATN/100)}{F_{in}\Delta t}$	S = spot area; t = time
Absorption coefficient:	$b_{abs} = \frac{b_{atn}}{C}$	C = multiple scattering parameter (Weingartner et al. 2003)
Black carbon concentration:	$BC = \frac{b_{abs}}{\sigma_{air}}$	σ_{air} = mass absorption cross-section
Loading effect compensation:	$BC = BC_{measured}/(1 - k * ATN)$	k = compensation parameter
Final equation:	$BC = \frac{S*(\Delta ATN_1/100)}{F_1(1-\zeta)*\sigma_{air}*C*(1-k*ATN_1)*\Delta t}$	

The optical absorption is measured at 7 wavelengths simultaneously. The data obtained from channel6 (measurement at 880nm) is the defining standard used for reporting black carbon concentration.

Black carbon concentration: BC = bc6

The data of the other channels are uses as for the source apportionment. Their respective wavelengths and the Mass Absorption Cross section used in the calculation are as follows:

Channel	**Measurement wavelength (nm)**	**Mass absorption cross-section (MAC)σair(m2/g)**
1	370	18.47
2	470	14.54
3	520	13.14
4	590	11.58
5	660	10.35
6	880	7.77
7	950	7.19

MAC depends on refractive index, water content, particle size, and mixing with other aerosol components.

3. Observation and Data Analysis

After the continuous measurement of Black Carbon concentration with the instrument Aethalometer (AE-33) in the period of October 1, 2017 to January 31, 2018.

The collected data has been further filtered and thoroughly analyzed. The data is thoroughly analyzed at IMD on Operation Basis and acquisition of data is time base of 60 second with flow rate of 2LPM. The sampling site (New Delhi, Lodi Road) is at IMD 78.27 E,27.8N and height 20m above the ground. And we observed and studied the temporal variation of equivalent black carbon concentration, biomass burning and fossil fuel emission as monthly diurnal mean variations, daily averaged variation, weekly temporal Diurnal variation and monthly mean variation has been analyzed based on the IST time zone.

The Monthly mean spectral variation of absorption at seven different wavelengths depicted in figure4

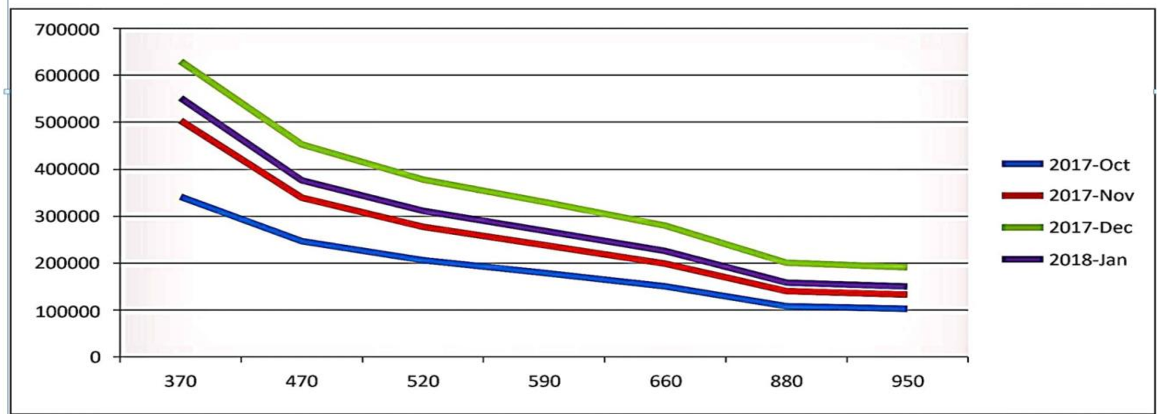

Fig 4: Monthly mean variation of Absorption at seven different wavelengths showing that the absorption is more at the shorter wavelength as compared to the higher wavelength, the higher degree of absorption at shorter wavelength is seen in the month of December 2017 and least in the October 2017

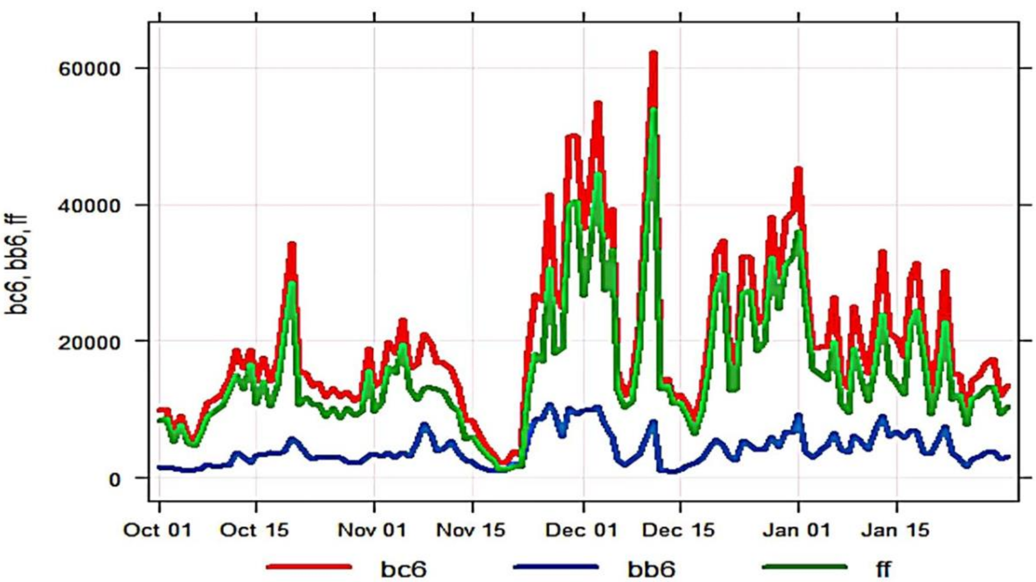

Fig 5: Temporal variation of equivalent Black Carbon (bc6), Biomass Burning (bb6), fossil fuel concentration (ff) in nanogram/m^3 showing the higher mass concentration of black carbon (bc6) biomass burning and the fossil fuel is in months of December (01 to 15)

The variation of pollutant concentrations by day of the weekis depicted in the figure 6.

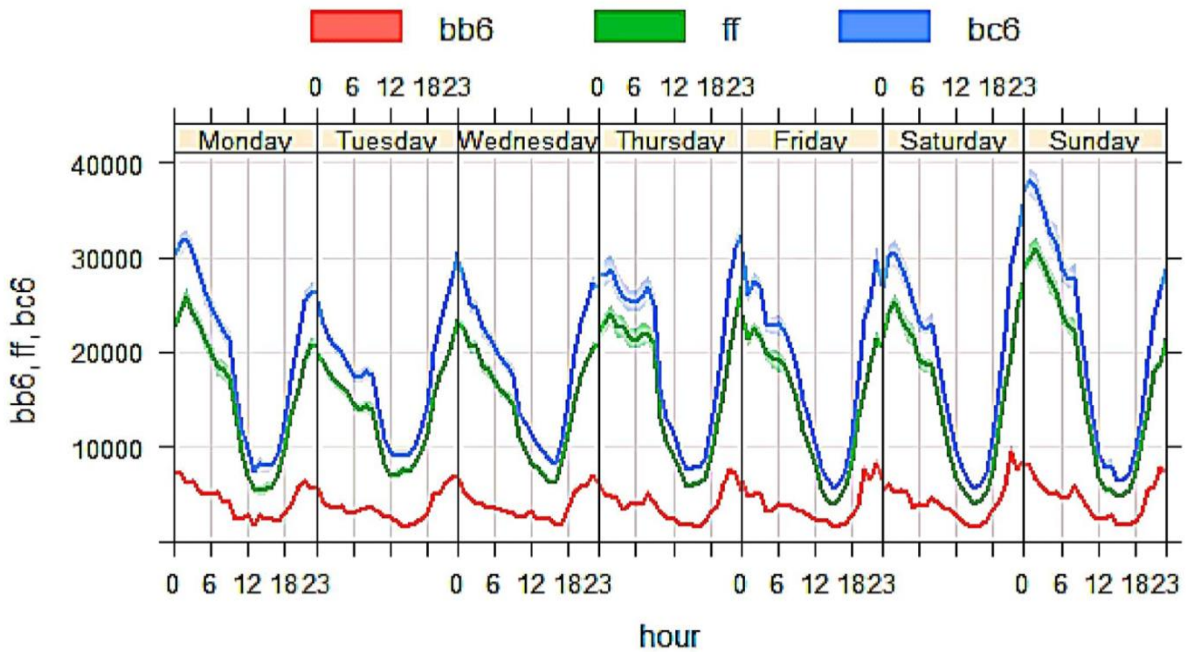

Fig 6: The weekly seasonal diurnal mean variation of Biomass burning (bb6), fossil fuel (ff) and black carbon (bc6) concentration (μg/m^3) showing the more concentration in the weekends as compared to the normal day

While the seasonal diurnal mean variation of biomass burning(bb6) and fossil fuel(ff)and Black carbon (bc6) is depicted in figure 7.

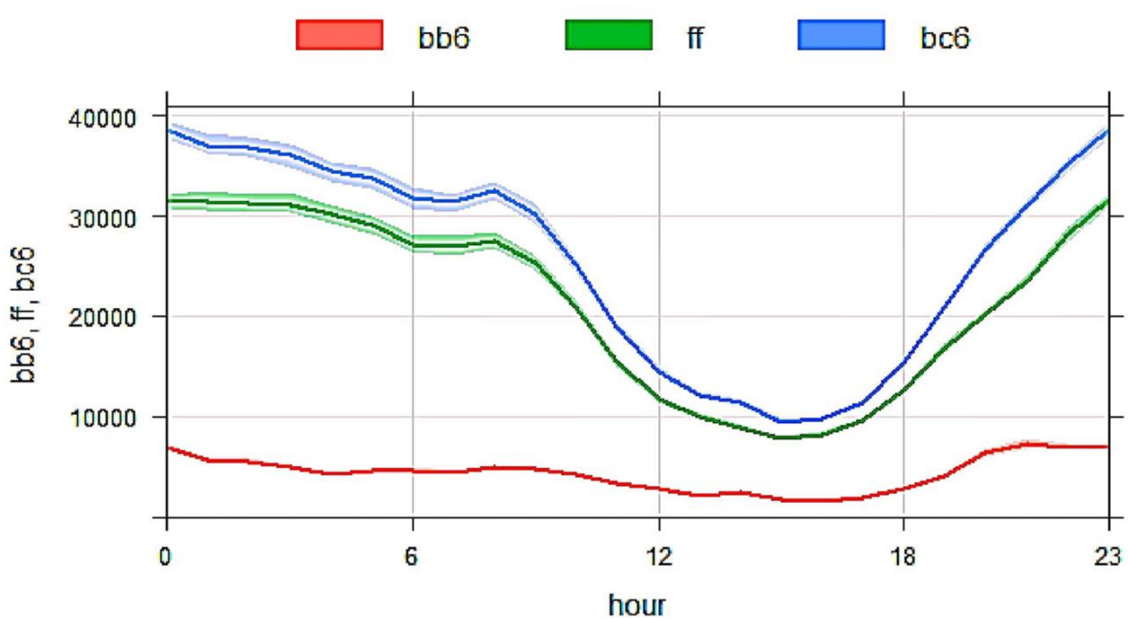

Fig 7: Seasonal Diurnal mean variation of biomass burning (bb6), fossil fuel (ff) and black carbon (bb6) concentration (μg/m^3) showing the more degree of concentration at the morning hours gradually decreasing in the afternoon with the increase in the evening time after the 1800 hour

Fig 8: Mean variation of compensation parameter (k6) showing the ageing of the aerosols present in the atmosphere as the more aged aerosols is seen the November month

The trend level variation in the concentration of biomass burning (bb6), black carbon (bc6), fossil fuel(ff) shown in the figure9 ,10 and 11respectively.

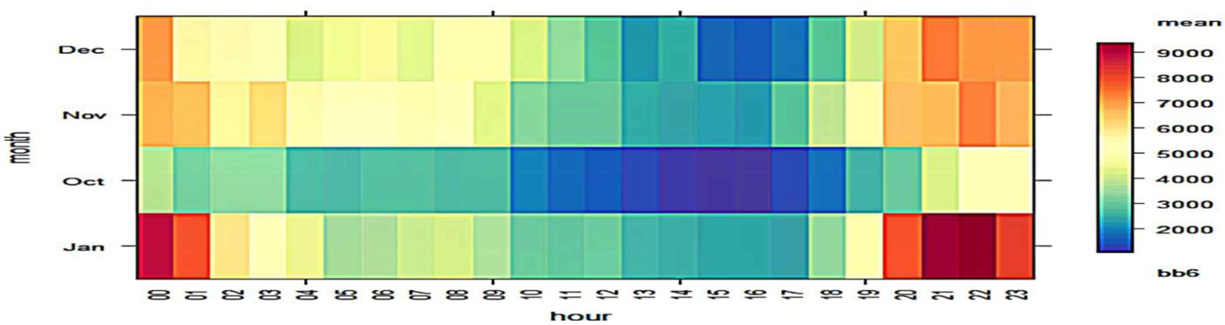

Fig 9: Trend Level Variation of biomass burning (bb6) showing the higher degree of biomass burning concentration during the night hours of January month

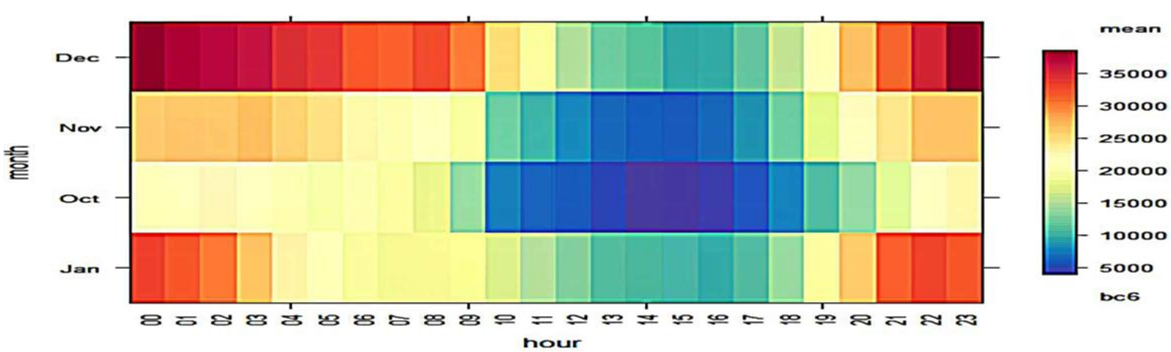

Fig 10: Trend level variation of Black Carbon (bc6) showing the higher degree of bc6 concentration in the late night and early morning hours in the month of December

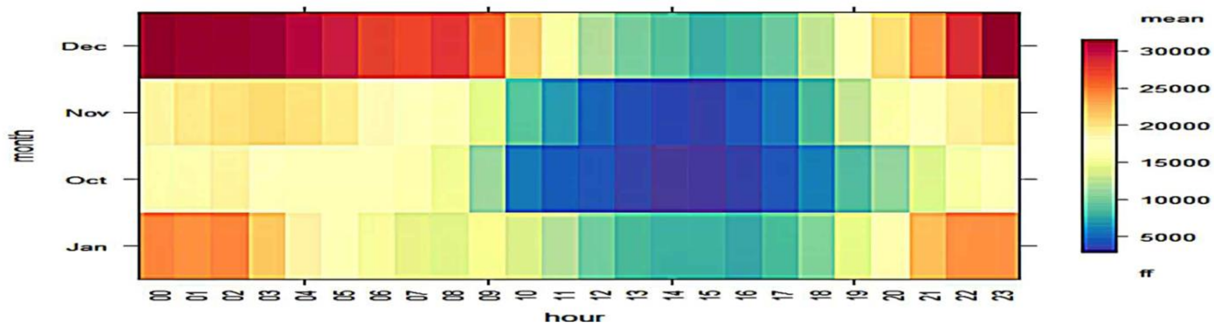

Fig 11: Trend Level variation of fossil fuel (ff) emission showing the higher degree of emission in the late night and early morning hours of December month

4. Result and Discussion

During the last four months (Oct 1, 2017 to Jan 31, 2018), it has been observed that the Mass concentration of black carbon aerosol in the New Delhi region was found to be increased in first three months (Oct, Nov, Dec 2017) and decrease in the January 2018, from the figure 1, the highest peak of monthly means is seen in the month of December i.e 25µg/m^3. While the lowest peak of monthly mean is seen in the October 2017 i.e. 13µg/m^3 during the study period.

We got the extensively high value of BC concentration in the month of December because of the lowering of temperature which leads to the lower boundary layer. Due to less dispersion of air mass and constant emission of pollutants from various sources giving high concentrations in the December month.

While the concentration of the biomass burning is seen increased in the month of October to November from 2.6µg/m^3 to 4.6µg/m^3 and shown decreased in month of December and again increased in January to 4.8µg/m^3. The extreme crop residue burning is the main reason to increase of biomass burning component in the equivalent Black Carbon. Anthropogenic activities like coal/wood burning to warm the interior of the room in the rural/urban areas in lowering of atmospheric temperature leads a raise of biomass burning in the December month which is an additional contribution to local emissions.

The monthly mean concentration of fossil fuel emission shows a highest value in the month of December to 21µg/m^3 and lowest value in October to 11µg/m^3. During the study of diurnal variation from Fig. 6 & 7, we observed that the mass concentration of black carbon, biomass burning and fossil fuel emission concentration was higher in early morning hours and late night hours, due the increase of heavy load vehicles in to the cities and lowering of atmospheric boundary layer which results in less dispersion of black carbon aerosol, thus consequent increase in its concentration.

In afternoon hours the BC concentration was decreased due to the increase in the boundary layer height. Irrespective from the boundary layer variations the effect of traffic intensity was also crucial factor as the vehicular emissions are one of the major sources for BC aerosols. So with the present study it can be predicted that BC concentrations are following the seasonal patterns. In which post monsoon and winter seasons shows high to extreme high values. The upcoming pre monsoon months and the values of black carbon (BC) concentration are going to be decreased due to rise in the temperature and dispersion of air mass.

The weekdays variation during the winter season shows the result that during weekends the BC concentration seems higher and during the weekdays it was lower comparable to, in which the highest concentrations are in early morning hours due to the large density of heavy load vehicles.

The monthly mean variation of compensation parameter (K6) which is an indicator of aged aerosols is shown in figure 8. Showing the ageing of aerosol means "the existence of aerosol in the atmosphere for longer duration" it may be due to the different atmospheric condition. The figure 8 shows the all the aerosols are aged aerosols which is greater than 0.006.

The absorption coefficient over seven different wavelengths depicted in figure 4. Shows the correct pattern as per MIE theory state the absorption at shorter wavelength is greater comparison to longer wavelength. The monthly mean absorption coefficient at 660nm is above 100 M/m.

Table 1 Monthly mean value of concentration of black carbon (bc6), biomass burning (bb6), fossil fuel (ff) and Alpha Concentration

Month	Black carbon(bc6) $\mu g/m^3$	Biomass burning (bb6) $\mu g/m^3$	Fossil fuel (ff) $\mu g/m^3$	Alpha
October 2017	13	2.6	11	1.34
November 2017	18	4.6	13	1.46
December 2017	25	4.3	21	1.29
January 2018	20	4.8	15	1.37

5. Conclusions

- It is interesting to find a single peak in the diurnal pattern, which is high starting from evening to the next day morning hours.
- Winter season stands for the highest BC concentration which is contributed by the various anthropogenic source and unfavorable meteorological conditions.
- Fine particle are high in the November month due to the extreme crop residue burnings in the northern parts of India.
- Aged aerosols are more in the observed location during the study period.

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