Study of aerosol black carbon during different weather conditions over Delhi

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Abstract

Black Carbon (BC) aerosols are the main sunlight-absorbing component of atmospheric aerosols. In this paper we present results of BC aerosols concentration at typical weather conditions over Delhi during June 2005 to June 2006 using an Aethalometer. We studied for foggy, rainy, dusty and very clear days. The BC concentration shows pronounced variations with weather changes. The annual average BC concentration was 16.32 $\mu g/m^3$ of which foggy days concentrations were maximum while the clear days were minimum. The average BC concentration during foggy days reaches up to ~50.39 $\mu g/m^3$ in comparison to clear days which peaks only upto ~6.8 $\mu g/m^3$, so foggy days values is 7.4 times more. Followed by foggy days, rainy days show the higher BC concentration. The average values are ~6.82 $\mu g/m^3$ and 6.9 $\mu g/m^3$ for dusty days and dust storm period respectively. The BC concentration shows strong anti-correlation with the mixing layer height measured simultaneously using an acoustic SODAR. Stronger anti- correlation (correlation coefficient –0.618) was found with the ventilation coefficients. The effect of BC aerosols over Radiative forcing has also been estimated using OPAC and SBDART model.

Keywords: Black carbon, Aethalometer, mixing layer height, Ventilation coefficients.

1. Introduction

Climate change poses potentially major challenges to social and economic development in all countries. Black carbon aerosols are one of the important factors in the global climate change phenomenon. This is mainly due to their absorptive nature, which directly accounts for the reduction in incoming short wave solar radiation. It is the graphitic form of carbonaceous aerosols emitted into the atmosphere as by-product of all combustion processes such as industrial pollution, traffic, outdoors fires, household burning of coal and biomass fuels The ability of carbonaceous aerosols to modify local meteorology and climatology in regions where emissions are high, like china and India, has been postulated (Ramanathan et al., 2001; Menon et al., 2002). Most of the BC are fine accumulation size particles (radius <0.2micrometer) which are hydrophobic or weakly hydrophilic *(Jacobson, 2001)* and have global residence times of about 1 week. It ultimately change the dynamics of the atmospheric boundary layer.

2. Location and General meteorology of the sampling site

The study area is Delhi, the capital city of India, which is densely populated as well as highly polluted mega city of the world. Delhi lies in the latitude 28.38 N, longitude 77.12 E. Area is 1483 Km² and density is 10340/Km². Delhi has a semi-arid climate. It has extreme weather conditions during peak summers temperature rises even beyond 45 ^oC. and in winter temperature may drop to below 3 ^oC. In the pre-monsoon period (April- June), frequent dust storms from western and north- western desert regions cause large scale loading of aerosols over Delhi. The rainy season is from July to September when the climate sometimes becomes very humid. The average annual rainfall is approximately 670 mm (27 inches). The monitoring have been carried out from June 2005 to June 2006 in the premises of NPL ,New Delhi.

3. Measurement Technique

Continuous observations on BC aerosols have been carried out by using an Aethalometer (Model AE-21, Magee Scientific, USA).In this method, atmospheric air is pumped through an inlet at the flow rate of about 2 litre/min^{-1}, which impinges on a quartz micro fiber strip. A light beam from a high intensity LED lamp is transmitted through

the sample deposit on the filter strip, at 880nm. The measurement of the attenuation of light beam is linearly proportional to the amount of BC deposited on filter strip. Observation were recorded at the time base of 5 minute interval. The instrument has been factory calibrated and reported error in BC estimates is ~ ±2 %.

The planetary boundary layer height has been measured with SODAR an acoustic echo sounder, which is developed, designed and fabricated in the NPL. Highly directional short burst of sound energy are radiated into the atmosphere, which after scattering from atmospheric fluctuations of eddy sizes within the inertial sub range (0. 1-10m), are received by the receiving antenna. Useful qualitative information about nocturnal inversions obtained by facsimile chart. This facsimile chart reveals the height of boundary layer in the atmosphere, which is working 24 hrs daily at NPL.

4. Results and Discussion

4.1 Seasonal changes in BC concentration

Results show variations of BC concentration on diurnal scales. The characteristic of BC also shows a strong weather dependent variation. In fig 1 strong correlation between BC concentration and atmospheric phenomenon has been shown.

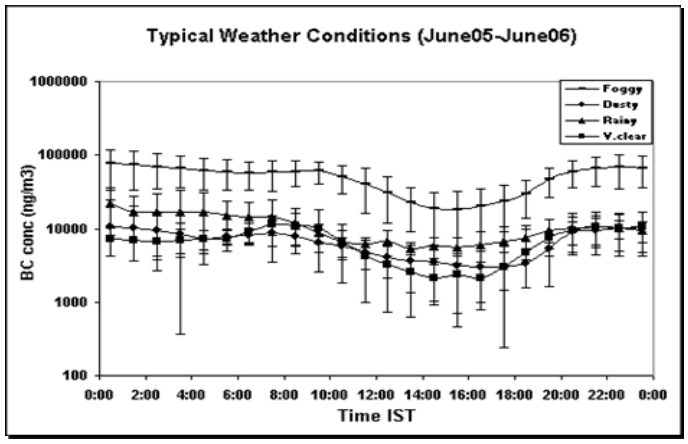

Fig 1: Diurnal variation of BC concentration during typical weather conditions.

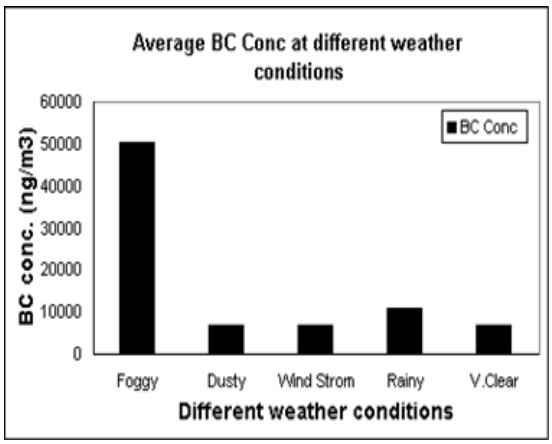

Fig 2: Average BC concentration during different weather conditions

Fig. 2 shows that the foggy days values are maximum while the clear days values were minimum. The maximum BC concentration during foggy days reaches upto 76.1 µg/m3 (0030h) whereas the minimum value 18. µg/m3 at (1530h). For clear day peaks reaches upto 10.6 µg/m3 at (0030h). The difference in BC concentration during foggy days is about 7.4 times more than clear days. Low mixing heights and low wind speeds during winter are conducive for the less dispersal of pollutants. Next maximum BC concentration value after foggy days are rainy days.The maximum and minimum values are 5.4 µg/m3(0030h) and 21.8 µg/m3 (1330h) respectively. This may be fact that BC may be trapped in clouds. The BC concentration significantly reduced after rainfall due to scavenging effect of rainfall and also due to reduction in the continental features conductive for aerosol generation by shifting the air mass *(K.M.Latha,K.V.S.Badrinath,Atmospheric Environment, 2005).* The lowest and highest values for dusty days are ~3µg/m3 (1430h)and 10.8 µg/m3 (0030h).

The annual average BC concentration at Delhi during June 2005-June 2006 was 16.32 µg/m3 , which is a good comparison with those reported a mean BC of 12.3µg/m3 for Kanpur, India by Tripathi et. al (2005) and 21.7µg/m3 at Lahore ,Pakistan by L.Hussain et al (2007). The average BC concentration was about 63% more during foggy days than the annual average and in rainy days it was about 13% more. Precipitation, scavenging plays a significant role in reducing the BC concentration.Whereas during dusty and windstrom periods, average BC concentration was about ~8%.

4.2 Comparison of BC concentration with Ventilation Coefficient

In fig 3, the variation of ventilation coefficient with respect to BC concentration for the entire monitoring period during the day time (1000 to 1700h) has been shown. Ventilation coefficient obtained by multiplying the average wind velocity with the mixing layer height

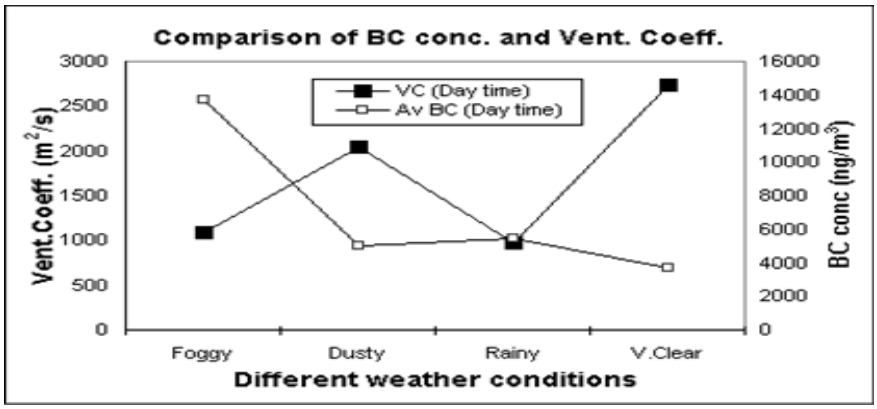

Fig 3: Comparison of BC concentration with Ventilation coefficients.

A clear anti- correlation (correlation coefficient –0.618) between the two was observed which indicates that the BC concentration largely depends on the ventilation coefficients. The highest BC concentration were usually observed when wind speeds were low, and the lowest concentrations during periods with the highest winds. As we can see except for the rainy season there is strong anti-correlation in between the BC concentration and the ventilation coefficient at different weather conditions. In rainy season, this may be attributed due to slow wind speeds in addition to low boundary layer.

4.3 Effects of BC concentration on Aerosol Radiation Forcing

Santa Barbara DISORT Atmospheric Radiative Transfer (SBDART) model (Ricchiazzi et al., 1198) was used to compute the net flux in the in the wavelength range 0.3-3.0mm with and without aerosols at the top of the atmosphere (TOA) and at the surface separately. The model was run at 1-h interval for a period and average forcing was estimated during each month for cloud free clear- sky conditions. Initially at $2mm^{-3}$ the TOA was negative, the surface forcing was also negative but as the concentration of BC increases the TOA forcing becomes positive & the surface forcing decreases from -30 to –75 W/m^2

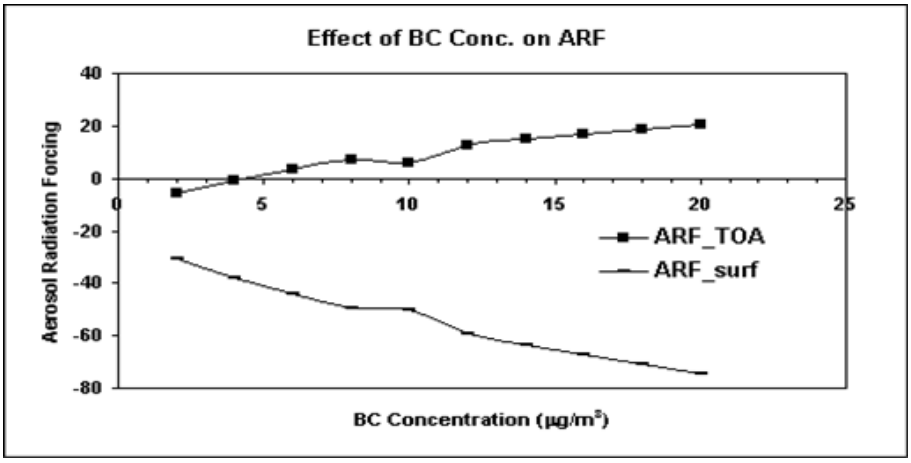

Fig. 4: Effect of BC concentration on Aerosol Radiation Forcing

5. Conclusions

BC concentration has been measured at semiarid mega city, Delhi, India by an Aethalometer. The key findings are**:**

1 BC exhibited a distinct diurnal variation with the highest concentration occurring 0630h to 0930h and again at around 2000h till midnight. And low concentration from ~1000h. The diurnal pattern was largely a result of changes in the mixing heights.

2 The annual average BC concentration was 16.32 µg/m3. Higher concentration was found for foggy weather. It is about 7.4 times more than the clear days.

3 The relationship between mixing layer height and BC concentration is anti-correlated. Strong anti- correlation (correlation coefficient –0.618) was found with the ventilation coefficients.

4 As the concentration of BC increases the TOA forcing becomes positive while the surface radiative forcing becomes negative.

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