ATMOSPHERIC BLACK CARBON OVER QATAR: SEASONAL VARIABILITY AND SOURCE APPORTIONMENT

Faculty and PostDoc, Energy and Environment

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AIM OF STUDY:

The earth's atmosphere contains minute particles suspended within it. These atmospheric particles influence the earth's radiation budget through their ability to absorb and scatter radiation (Lewis et al., 2008). Black carbon (BC) is a type of carbonaceous particle, characterized by highly absorbing solar radiation. Unlike sulfate and sea-salt aerosols, black carbon causes positive radiative forcing due to its absorbing nature. With the greenhouses gases accumulation in the atmosphere, the average temperature of the world increased by 1.09°C (IPCC, 2021), between 1850-1900 and the last decade. Since black carbon is one of the major light-absorbing components of aerosol, there is a need to assess BC concentration, their origin, and the contribution of both human-induced combustion and biomass burning emissions to BC levels. In this study, measurements of aerosol absorption at seven wavelengths were investigated in order to determine the daily and seasonal behavior of black carbon and contribution of fossil fuel (FF) and biomass burning (BB) emissions to total BC mass concentration in a suburban area located north of Doha.

SITE DESCRIPTION AND INSTRUMENTATION:

Figure 1. Location of sampling site: a suburban area situated in north of Doha (25.37° N, 51.48° E), Qatar.

- BC was measured continuously in 1-min resolution using a seven wavelengths Aethalometer (Magee Scientific model AE33, wavelength λ = 370, 470, 520, 590, 660, 880 and 950 nm) (Drinovec et al., 2015).
- Black carbon measurement campaign was commenced in October 2016 and ended in September 2020, with temporal gaps.
- All raw measurements were screened for irregular values. Negative and single extreme values were regarded as invalid and discarded.

Spectral absorption of biomass and fossil fuel emissions show different characteristic. Therefore it is possible to allocate equivalent black carbon to these two compounds by using the Aethalometer (Sandradewi et al., 2008). Assuming absorption resulting from fossil fuel and biomass, total absorption coefficient at wavelength λ can be explained as follow;

$B_{abs}(\lambda) = B_{abs}(\lambda)_{ff} + B_{abs}(\lambda)_{bb}$, where ff and bb represents absorption coefficient of fossil fuel and biomass, respectively.

$AAE(\lambda_1, \lambda_2) = -\frac{\ln(B_{abs}(\lambda_1)/B_{abs}(\lambda_2))}{\ln(\lambda 1/\lambda 2)}$ gives information about aerosol composition based on the Angstrom exponent (Angstrom, 1992). BC originated from fossil fuel shows weak wavelength dependency (AAE ~ 1) whereas BC from biomass exhibits enhanced absorption at shorter wavelengths (AAE >1).

The source apportionment of BC was applied using following equations at two wavelengths.

$$\frac{B_{abs}(470\,nm)_{ff}}{B_{abs}(950\,nm)_{ff}} = \left(\frac{470}{950}\right)^{-AAE_{ff}} \quad , \quad \frac{B_{abs}(470\,nm)_{bb}}{B_{abs}(950\,nm)_{bb}} = \left(\frac{470}{950}\right)^{-AAE_{bb}}$$

$$B_{abs}(470\,nm) = B_{abs}(470\,nm)_{ff} + B_{abs}(470\,nm)_{bb}$$

$$B_{abs}(950\,nm) = B_{abs}(950\,nm)_{ff} + B_{abs}(950\,nm)_{bb}$$

Biomass burning and traffic BC fractions were then calculated as :

$BB(\%) = \frac{B_{abs}(950\,nm)_{bb}}{B_{abs}(950\,nm)}$, BC_{bb} = BB * BC , BC_{ff} = (1-BB) * BC

FINAL REMARKS:

Four-year aerosol spectral light absorption measurements obtained from Doha, Qatar were analyzed to determine their daily and seasonal behavior, source identification and quantification of BC according to biomass burning and fossil fuel sources. The highest concentrations of BC were observed during the winter and the lowest values during the summer. Fossil fuel emissions were found to be the major source of BC levels. Nonetheless, the influence of biomass burning should not be disregarded. Future studies must be done to fully identify the enhanced absorption in shorter wavelength.

References:

Drinovec, L., Močnik, G., Zotter, P., Prévôt, A.S.H., Ruckstuhl, C., Coz, E., Rupakheti, M., Sciare, J., Müller, T., Wiedensohler, A., Hansen, A.D.A., 2015. The "dual-spot" aethalometer: an improved measurement of aerosol black carbon with real-time loading compensation. Atmos. Meas. Tech. 8 (5), 1965–1979.

Sandradewi, J.; Prévôt, A.S.H.;Weingartner, E.; Schmidhauser, R.; Gysel, M.; Baltensperger, U. A study of wood burning and traffic aerosols in an Alpine valley using a multi-wavelength Aethalometer. Atmos. Environ. 2008, 42, 101–112.

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RESULTS:

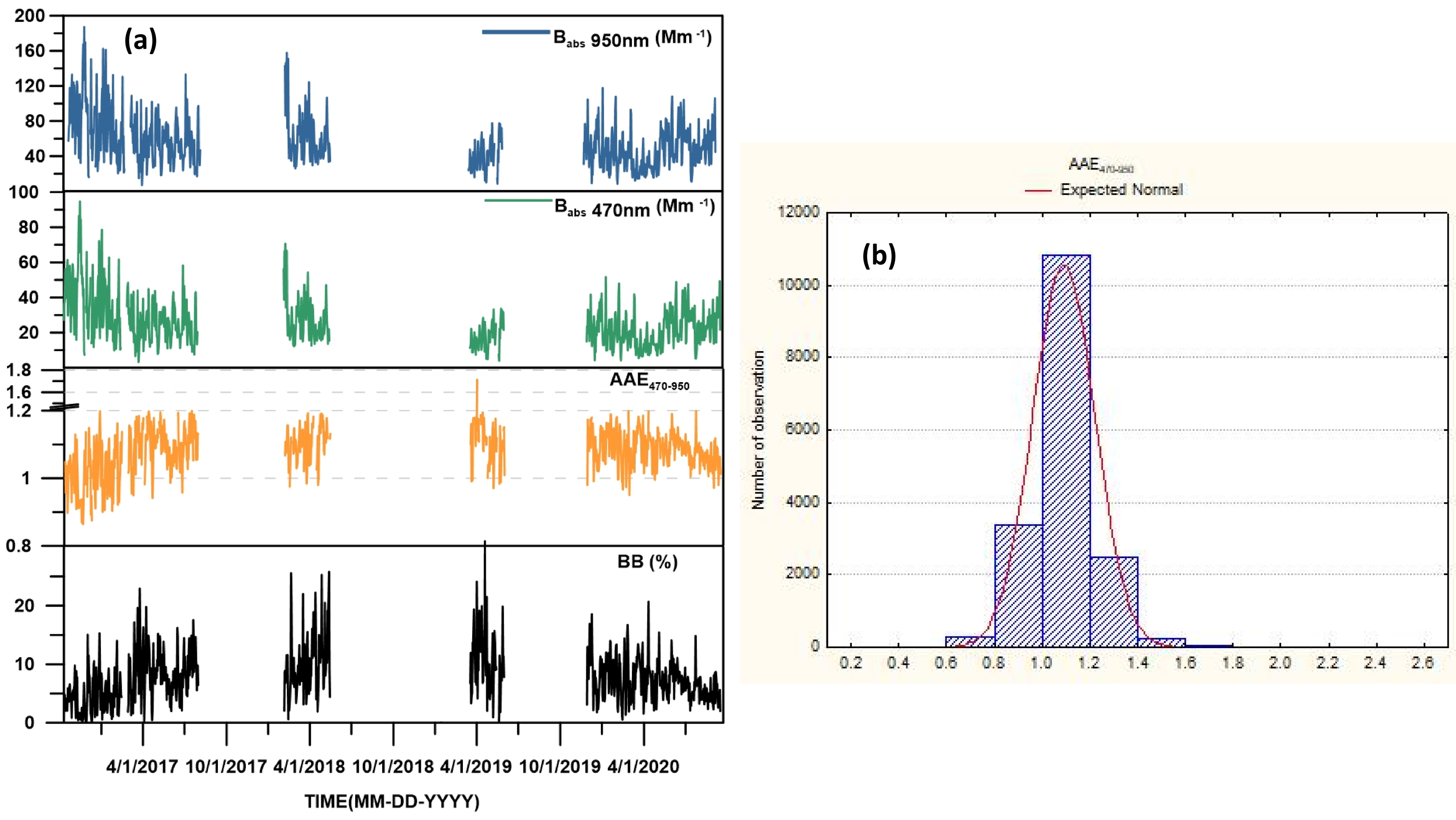

Figure 2. Daily variability (a) in B_{abs} 950nm , B_{abs} 470nm, $AAE_{470\text{-}950}$ and BB (%), (b) frequency histogram of AAE values

- B_{abs} at 470 nm (950 nm) showed large daily variability, ranging from 7 (3) to 187 (95) Mm^{-1}. The mean B_{abs} at 470 nm and 950 nm for the full period was 55 ± 29 Mm^{-1} and 25 ± 13 Mm^{-1}, respectively.
- About 80% of the AAEs fluctuated between 0.8 and 1.2, suggesting the significant contribution from fossil fuel emissions.

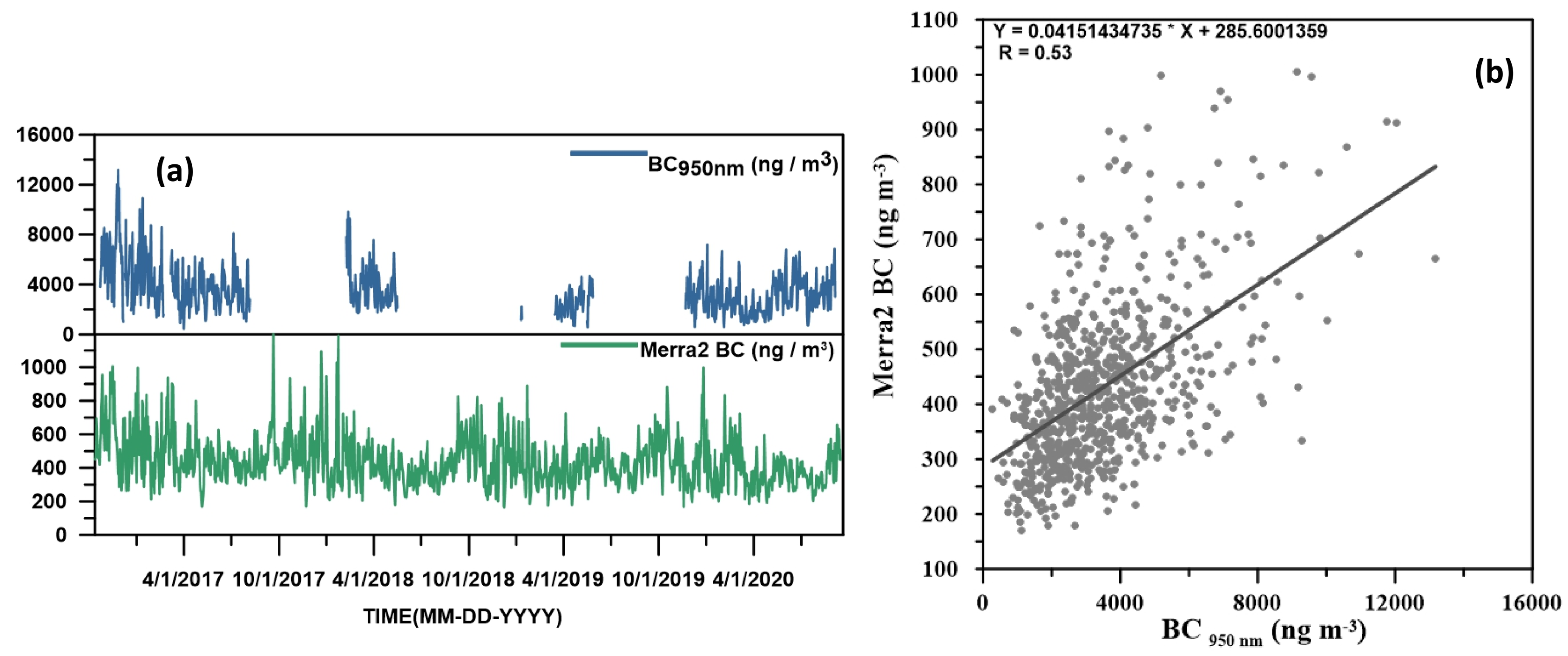

Figure 3. Time series of (a) BC from Aethalometer and MERRA2 reanalysis surface BC concentrations, (b) regression analysis between them.

When compared BC from Aethalometer with MERRA2 reanalysis surface BC concentrations, it was observed that the ground BC concentrations displayed moderate correlation with MERRA2 reanalysis (R=0.53) ; nevertheless, the daily ground BC levels were one order of magnitude larger than MERRA2 reanalysis. This discrepancy may be attributed to local sources and probable absorption from mineral dust.

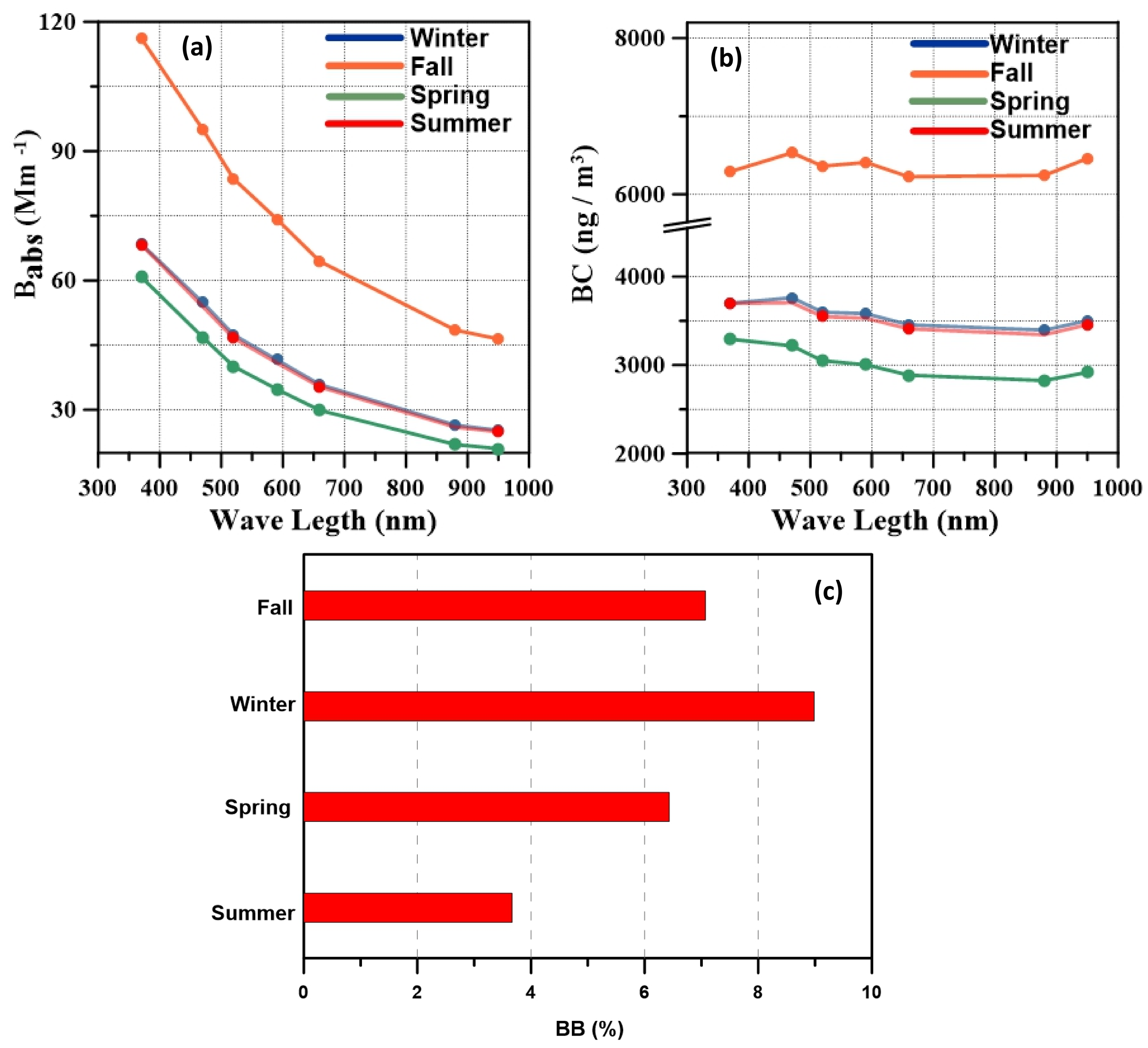

Figure 4. Seasonal spectral dependency of B_{ABS} and BC. Winter: (D-J-F-M),Spring: (A-M), Summer: (J-J-A-S) and Fall: (N-O).

- Absorption coefficient and consequently BC values were found higher during winter than that observed in others season, showing statistically significant difference between summer and winter. This can be related to decrease in planetary boundary layer during winter time.
- The source apportionment showed that BC was dominated by fossil-fuel sources. The mean percentage of BB (%) was 7 ± 5, suggesting that biomass emission contribution to the total BC absorption is so limited.