Recent Developments in the UK Black Carbon Network

Long Term Changes in BC/EC ratios

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Background

Black carbon (BC) is one of the most influential anthropogenic agents of climate change and negative health effects. Its source in the atmosphere is generally combustion emissions such as vehicle exhausts (especially unfiltered diesel type), domestic and industrial coal, heavy oil and wood burning, as well as forest and vegetation fires [1]. In September 2006 the National Physical Laboratory (NPL) in partnership with the Environmental Research Group at King's College London (KCL) was awarded the contract to run an air quality network which currently provides data from 14 sites across the mainland UK.

The measurement of BC is based on light-absorption by atmospheric aerosol particles and two wavelength aethalometers AE22 are in use. In addition to UK Black Carbon Network, also elemental carbon (EC) is measured by a thermo-optical (chemical) technique to provide results of soot-like carbonaceous material. EC, however, essentially splits the total carbon between organic carbon (OC) and EC, and this strongly depends on the method chosen. There are consequently difficulties when comparing and interpreting the results from BC and EC measurements.

Methods

Black Carbon was measured by multiwavelength aethalometer AE22 (filter-based attenuation measurement) where the 880 nm wavelength is used together with a "Virkkula" loading correction to measure BC concentration of the aerosol. The analysis of EC/OC was carried out using Sunset Laboratory Inc. thermal/optical carbon analyser with 1.5 cm^2 punch taken from quartz filters using the EUSAAR2 protocol.

Data for this comparison are the results of the measurements at three of UK's Air Quality Network sites i.e.: Chilbolton (CH) for a rural background, and North Kensington (NK) and Marylebone Road (MR) sites both located in London.

Results (1)

The daily-averaged aethalometer concentrations (BC) were plotted against daily Elemental Carbon (EC) measurements and the annual regression (using the reduced Major Axis method) was calculated for each site (see Table 1, Fig 1). Results from 2018 were as follows: 1.24x-0.04 for CH, 1.01x-0.03 for NK and 1.03x+0.06 for MR. R^2 parameters were 0.85, 0.90 and 0.90, respectively, showing good linear relationship.

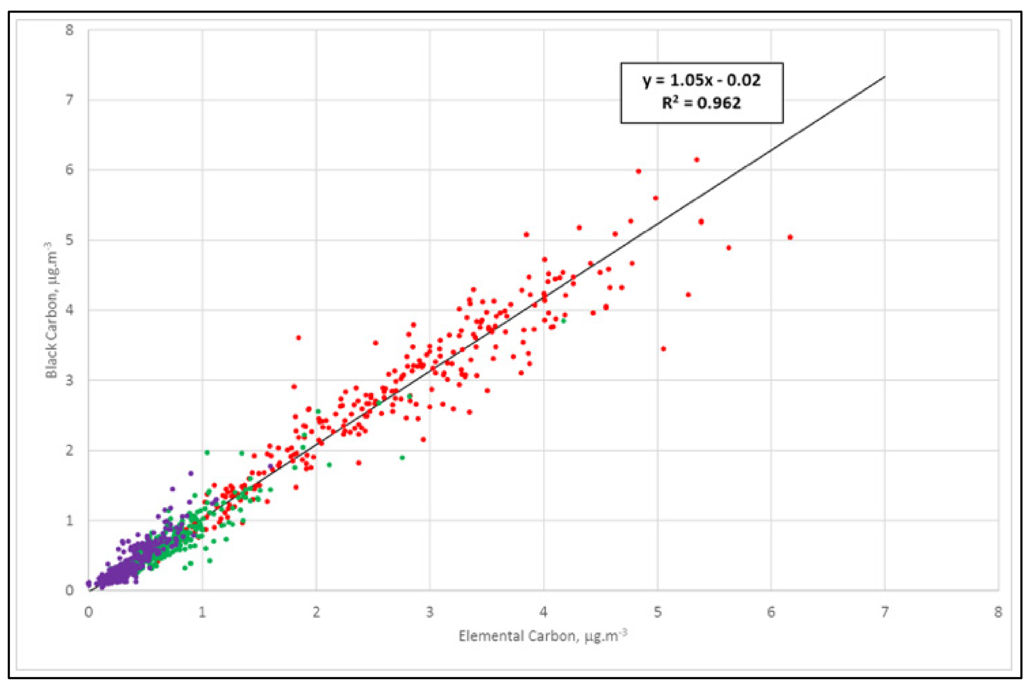

Fig 1. Black Carbon and Elemental Carbon measurements for all 3 sites in 2018. RED – Marylebone Road; Green – North Kensington; Purple – Chilbolton

Table 1. *Relationship between Black Carbon (y-axis) and Elemental Carbon (x-axis) over the period 2009 - 2018; (in µg·m^{-3}). The rural data from 2016 onwards are from Chilbolton and so may not be directly comparable to previous years.*

	Harwell/ Chilbolton		North Kensington		Marylebone Road	
Year	Relationship	R^2	Relationship	R^2	Relationship	R^2
2009	N/A*	N/A	1.05 x + 0.20	0.858	1.36 x - 0.69	0.776
2010	1.32 x + 0.06	0.555	1.37 x – 0.32	0.734	1.28 x + 0.56	0.946
2011	1.52 x + 0.18	0.844	1.26 x + 0.07	0.810	1.50 x - 0.35	0.924
2012	1.84 x + 0.06	0.908	1.42 x + 0.17	0.906	1.43 x + 0.01	0.898
2013	1.74 x + 0.17	0.865	1.59 x + 0.33	0.871	1.47 x + 0.39	0.679
2014	2.02 x - 0.01	0.802	1.68 x - 0.00	0.872	1.32 x + 0.25	0.819
2015	1.67 x - 0.03	0.833	1.64 x - 0.17	0.893	1.23 x + 0.28	0.901
2016	1.31 x + 0.03	0.887	1.08 x + 0.03	0.958	1.25 x + 0.26	0.953
2017	0.92 x + 0.02	0.827	1.04 x - 0.01	0.939	1.15 x + 0.02	0.902
2018	1.24 x – 0.04	0.852	1.01 x – 0.03	0.900	1.03 x + 0.06	0.899

Conclusions

In general, the chemically based Elemental Carbon metric and the optically based Black Carbon metric both quantify the "soot" component of airborne particles and ideally should give the same results [3]. There has been a remarkable decrease in concentration in both BC and EC at Marylebone Road in recent years. The observed decrease in BC/EC ratio could be due to "soot" particles becoming less absorbing per unit mass, or to a decrease in absorbing non-carbonaceous particles. However, because these two methods are based on entirely independent principles and moreover are not yet traceable or standardised, the change in ratio may be a measurement artefact. One way forward would be to develop and characterise new "representative" sources to improve accuracy in the field of black carbon measurement.

Results (2)

Long term (2009-2018) BC and EC monthly-averaged concentrations are presented in Fig 2. and Fig 3. These plots are based on results from Marylebone Road and North Kensington sites representing London roadside and urban background, respectively. BC/EC ratios were calculated, and both sites were juxtaposed in Fig 4. Charts and linear regressions were generated by R software (red line) with lower and upper limits (in µg·m^{-3}) using Theil-Sen method.

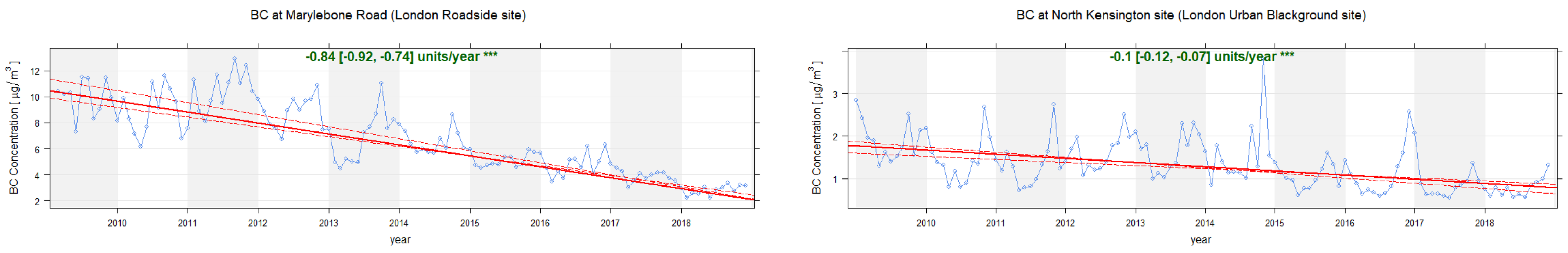

Fig 2. Black Carbon trends in monthly-averages measured at Marylebone Road (left) and North Kensington (right).

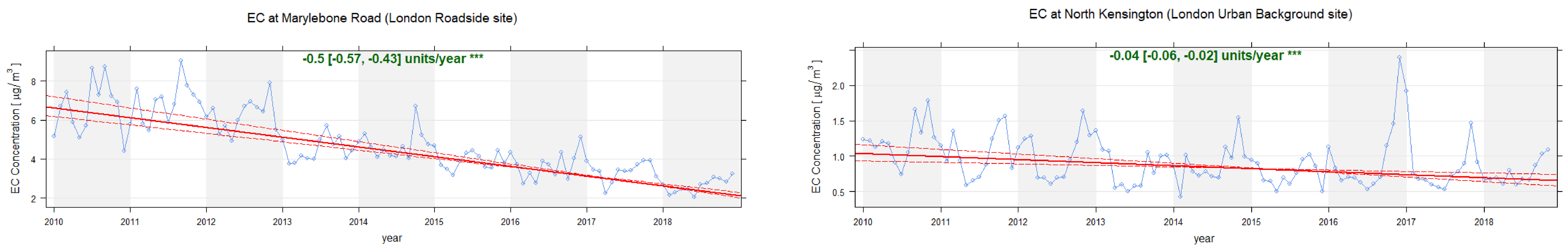

Fig 3. Elemental Carbon trends in monthly-averages measured at Marylebone Road (left) and North Kensington (right).

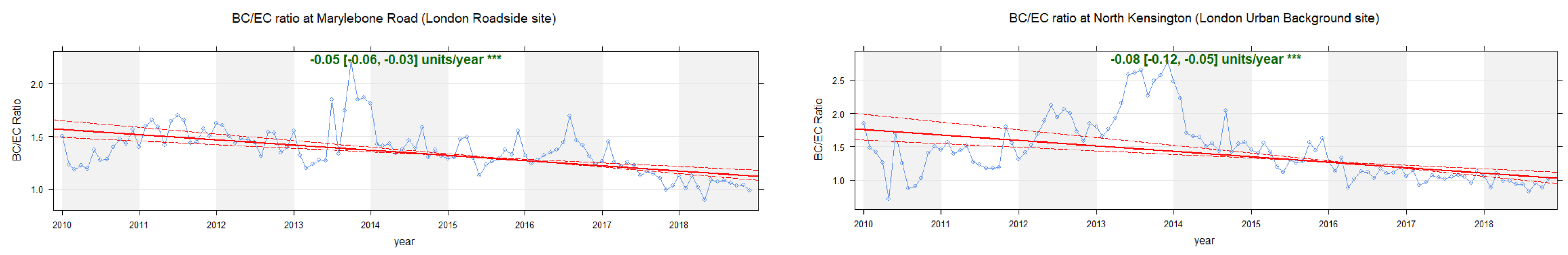

Fig 4. BC/EC ratios calculated for Marylebone Road (left) and North Kensington (right).

Observations (1 & 2)

In 2018 black carbon and elemental carbon measurements for all 3 sites (see Fig 1.) showed good correlation between both methods (slope 1.05). However, this relationship for each site separately did not show such good agreement over the given period, 2009-2018.

Long term measurements at the Marylebone Road and North Kensington sites might indicate a possible downwards trends in the BC/ EC slope over time. It is especially seen at MR site where BC and EC concentrations decreased dramatically by a factor of 3-5 over 10 years. Slopes, however, were different at NK, where concentration decreased by a factor of 2 over 10 years. The BC/EC ratios show downward trends indicating a change in particle composition that affects the measurement methods differently.

Results (3)

BC and EC temporal variations (by day/month) have been calculated on a basis of long-term measurements (2009-2018) for Marylebone Road and North Kensington sites (see Fig 5.). These were compared with BC/EC ratios calculated for the same period with temporal variations by day and by month (see Fig 6.).

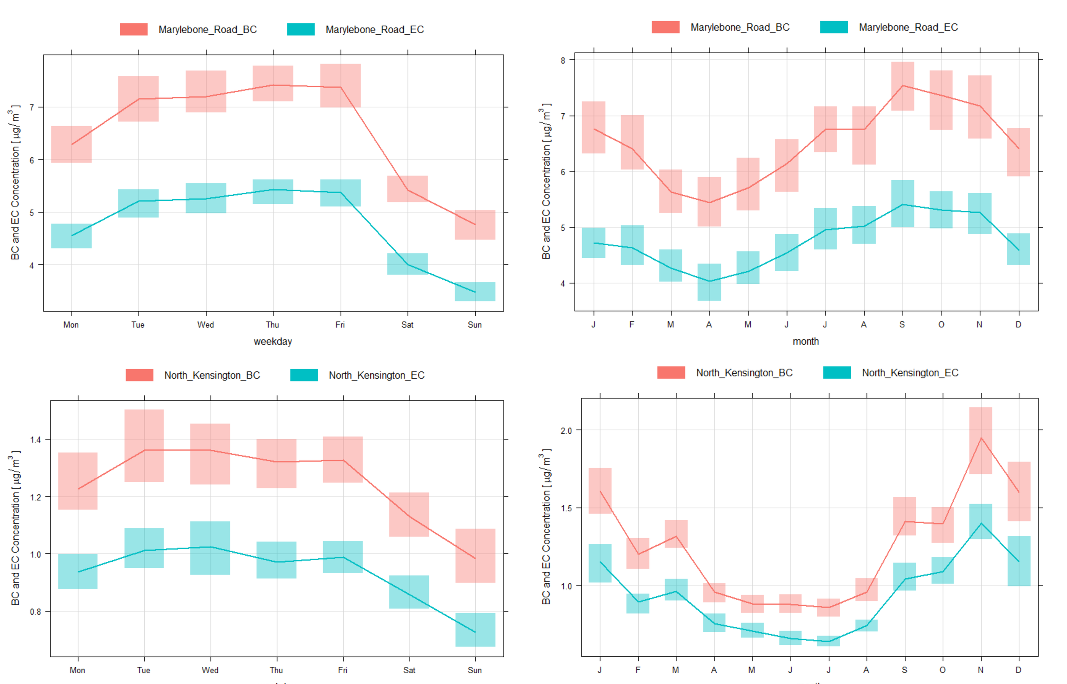

Fig 5. BC and EC temporal variations at Marylebone Road (top) and North Kensington (bottom) by weekdays (left) and month (right).

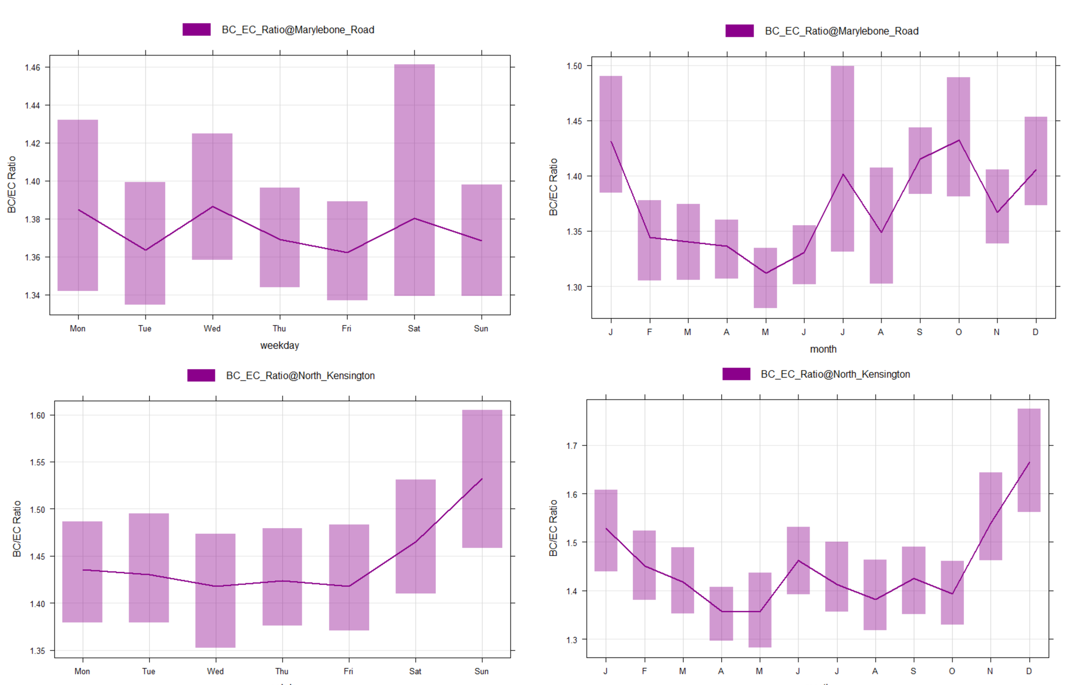

Fig 6. BC/EC ratios at Marylebone Road (top) and North Kensington (bottom) by weekdays (left) and month (right).

Observation (3)

Data show clear weekly and yearly variations for BC and EC concentrations and both components follow a similar pattern (see Fig 5). Concentrations together with BC/EC ratios suggest seasonal dependence with minimum values in spring for Marylebone Road and in summer for North Kensington. It was noticed that although both sites show decrease in concentrations during weekends, at North Kensington site BC/EC ratio slightly increases, whereas at MR the weekend ratio is similar to the ratio during the week.

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References

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