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Real-Time Performance of the microAeth® AE51 and the Effects of Aerosol Loading on Its Measurement Results at a Traffic Site

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ABSTRACT

The new portable microAeth® AE51 (AE51) is very useful for assessing occupational and environmental exposure to black carbon (BC) aerosols in epidemiological research. However, information about the performance of AE51 is limited. This study compares AE51 with the widely used, rack-mounted Aethalometer® AE31 (AE31) by evaluating the real-time performance of these two instruments, as carried out at a traffic site. Additionally, an optimized noise-reduction averaging (ONA) algorithm is adopted to eliminate the negative values in the BC data sets. Negative BC levels may be present using AE51 at low actual BC levels or at a high time-resolution. The negative values can be eliminated very effectively by the ONA method. The time-variation of the 5 min BC levels measured using AE51 is highly consistent with that measured using AE31. Loading effects on the measured BC levels are observed during the sampling period. Additionally, the correcting factor, *k*, is evaluated, in which the correcting factors are 0.0033 and 0.0039 for AE31 and AE51, respectively, when used to monitor the BC levels at this traffic site. The analytical results indicate that the BC levels are underestimated by up to 15% when the ATN-ATN_0 increases to ~40. The measurement results also reveal that the BC levels measured by AE51 are approximately 14% higher than those measured using AE31. These results may be due to the different aerosol deposition velocities and mass attenuation cross-section parameters (σ_{ATN}) of the two instruments.

Keywords: Black carbon; Traffic site; Loading effect; Aethalometer; AE31; AE51.

INTRODUCTION

Black carbon (BC) aerosols are formed by the incomplete combustion of fuels and are important atmospheric components because of their potentially negative effects on climate and health (Jacobson, 2002; Watson, 2002). BC absorbs visible solar radiation in the atmosphere, and has been identified as a major contributor to global warming (Jacobson, 2001; Badarinath and Latha, 2006; Ramanathan and Carmichael, 2008; Jacobson, 2010; Bond *et al.*, 2013). BC also associated with many respiratory diseases and detrimentally affects the cardiovascular system (Rich *et al.*, 2005; Jansen *et al.*, 2005; Suglia *et al.*, 2008a, b; Power *et al.*, 2011).

The most common method for measuring BC involves collecting aerosols on a filter and measuring the reduction of the transmission of light through the filter (Hansen *et al.*, 1984). The Aethalometer® (AE; Magee Scientific), multi-angle absorption photometer (MAAP; Thermo Scientific), and the particle soot absorption photometer (PSAP; Radiance Research) are among the devices that are currently available for measuring BC using filter-based optical techniques. They have been used extensively to monitor environmental BC levels because of their ease of operation, and favorable time resolution (Watson *et al.*, 2005; Park *et al.*, 2006; Chow *et al.*, 2009). Such online measurement instruments are critical to research studies that seek to characterize short-term and/or long-term variability in BC levels, such as by measuring source emissions that change rapidly, comparing time-varying outdoor/indoor air pollution levels, or observing dynamic trends in ambient air quality (Badarinath and Latha, 2006; Fruin *et al.*, 2008; Rodríguez *et al.*, 2008; Sandradewi *et al.*, 2008; Dutkiewicz *et al.*, 2009; Wang *et al.*, 2009; Snyder *et al.*, 2010; Boogaard *et al.*, 2011; Hyvärinen *et al.*, 2011; Reche *et al.*, 2011; Viana *et al.*, 2011; Wang *et al.*, 2011; Reddy *et al.*, 2012; Wang *et al.*, 2012; Cheng *et al.*, 2013). They also could be used to evaluate the light absorption coefficient of aerosol by measuring the attenuation of light through deposited aerosol (Lavanchy *et al.*, 1999; Weingartner *et al.*, 2003; Arnott *et al.*, 2005; Fialho *et al.*, 2005; Schmid *et al.*, 2006).

A portable, lightweight, compact, inexpensive, easily

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operated, and battery-powered microAeth® AE51 (AE51; AethLabs, San Francisco, CA, USA) was developed recently for measuring personal exposure to BC, ambient vertical profile of BC, and emissions of BC from indoor sources. This instrument is very useful in assessing occupational and environmental exposure to BC aerosols in epidemiological research. Most recently, this portable AE51 has been used to monitor personal exposure (Apte *et al.*, 2011; Dons *et al.*, 2011; Invernizzi *et al.*, 2011; Stabile *et al.*, 2012; Buonanno *et al.*, 2013), and in which a balloon was raised to perform vertical profile sampling (Babu *et al.*, 2011; Ferrero *et al.*, 2011). However, information about the performance of AE51 is limited. Viana *et al.* (2010) demonstrated that 10 min BC levels measured by AE51 were approximately 16% lower than those measured by MAAP. Additionally, Babu *et al.* (2011) indicated that BC levels of under 3000 ng/m^3 measured by AE51 were approximately 13% lower than those measured by Aethalometer® AE31. Nevertheless, the statistical correlation between the measurements made using these two instruments is fairly good.

This study compares AE51 with an extensively adopted, rack-mounted Aethalometer® AE31 by evaluating their real-time performance at a traffic site. The real-time performance of AE51 is discussed under different sampling time intervals. As is well known, filter-based light absorption methods for measuring BC suffers from a "loading effect", in which the instrument underestimates BC levels proportionally with increasing aerosol loading on filter (Weingartner *et al.*, 2003). The aerosol loading effects on measurement results of BC levels using these two Aethalometers is also evaluated. Analytical results provide the correcting factors for these two Aethalometers to adjust the measured BC levels affected by the aerosol loading on the filter.

MATERIAL AND METHODS

Sampling Equipment and Data Collection

In this study, an Aethalometer® AE31 (AE31; Magee Scientific, Berkeley, CA, USA) and a microAeth® AE51 (AE51; AethLabs, San Francisco, CA, USA) were used simultaneously to measure BC levels at a traffic site. The sampling site in this study is selected on an urban roadside close to an arterial road near the campus of Fu Jen Catholic University at Xinzhuang, Taipei, Taiwan. The primary local source of atmospheric particulate matter at this sampling site is traffic. Inlets of these two aethalometers were located roughly 1.5 m above ground level.

These two Aethalometers operate on the same principles. The attenuation of light (ATN) from an LED source and transmitted through a fibrous filter that is loaded by the aerosols is measured. The ATN is defined as:

$$\mathrm{ATN} = 100 \cdot \ln\left(\frac{I_0}{I}\right) \tag{1}$$

where I_0 and I are the intensities of light that is transmitted through a reference blank spot and light that is transmitted through the spot of aerosol on the filter, respectively. These data are used to estimate the BC concentration using (Hansen *et al.*, 1984):

$$\mathrm{BC} = \frac{10^9}{\sigma_{\mathrm{ATN}}} \cdot \left[\frac{A \cdot \Delta\mathrm{ATN}}{100 \cdot Q \cdot \Delta t}\right] \tag{2}$$

where BC is the BC concentration in ng/m^3; A is the area of the sample spot in m^2; Q is the volumetric flow rate in m^3/s; Δt is the sampling interval in s; ΔATN is the variation in the ATN during the period Δt, and σ_{ATN} is the apparent mass attenuation cross-section for the black carbon that is collected on the filter in m^2/g. Table 1 presents the operating parameters for AE31 and AE51. The σ_{ATN} is provided by the manufacturer, and it depends on the wavelength used and the filter material.

Very high time-resolution data are obtained from AE51. Therefore, the sampling/logging time interval of AE51 was set to 1 s, 60 s, and 5 min (AE51 can only be set at these three time intervals). Unfortunately, AE31 could not be performed at a high time-resolution condition, owing to that the minimum time base of AE31 is 2 min. However, both Aethalometer instruments were compared at the same sampling interval of 5 min. Therefore, the logging time interval of AE31 was set at 5 min during all sampling periods. At each selected sampling interval of AE51, both Aethalometer instruments were compared for approximately 20–25 hours at the sampling site. The measurements were taken between 9:00 and 18:00, from February 6 to March 2, 2012.

BC levels measured using Aethalometer can be underestimated proportionally by increasing the filter loading (ATN value) (Weingartner *et al.*, 2003). However, this artifact minimally affects the BC levels at a low ATN.

Table 1. Operating parameters of AE31 and AE51 in this study.

	AE31	AE51
Wavelength number	seven-wavelength	single-wavelength
Volumetric flow rate, Q	8.33×10^{-5} m^3/s	1.67×10^{-6} m^3/s
Measurement period, Δt	300 s	1 s, 60 s, 300 s
Sample spot area, A	1.35×10^{-4} m^2	7.07×10^{-6} m^2
Deposition velocity, Q/A	0.62 m/s	0.24 m/s
Attenuation parameter, σ_{ATN} [a]	16.6 m^2/g	12.5 m^2/g
Filter material	Quartz fiber filter tape	PTFE-coated borosilicate glass fiber filter ticket

[a] at optical wavelength λ = 880 nm

In this study, the filter ticket in AE51 was replaced every 3–4 hours to prevent overloading of aerosols and maintain measurement integrity (keep all ATN < 40). The filter tape in AE31 was shifted automatically to expose a pristine spot on the filter when ATN value rose to ~35 (λ = 880 nm). In this study, the loading effects on measured BC levels were considered through an empirical correction algorithm, even though ATN was maintained at a low value during the sampling periods.

Post-Processing of Data

The BC data sets obtained using the Aethalometer instruments include negative values when sampling is performed at low concentrations or at a high time-resolution (short sampling/logging time interval). When the sampling interval is very short or the actual BC levels are very low, instrumental noise can cause ATN values to remain unchanged or even to decline slightly from one period to the next. This noise may result in an erroneously low value at one time followed by an erroneously high value at the next; or vice versa.

Hagler *et al.* (2011) developed a post-processing method to eliminate the noise in real-time data obtained using Aethalometer instruments. This optimized noise-reduction averaging (ONA) algorithm was adopted in this study to eliminate the negative values from BC data sets. It is available on the US EPA website (http://www.epa.gov/ordntrnt/ORD/NRMRL/appcd/mmd/ona.html). For use in the ONA method, a minimum delta attenuation (ΔATN_{min}) value of 0.05 is suggested to minimize the noise in the BC data (Hagler *et al.*, 2011). While Hagler *et al.* (2011) noted that even setting the ΔATN_{min} value to zero still reduces noise significantly, since the algorithm will smooth over periods where delta ATN fluctuates up and down. To maximize the time resolution of BC data in this study, the ΔATN_{min} in the ONA method was set to zero to eliminate all negative BC values from the data sets obtained using AE51. The 5 min averaged BC levels of AE51 were calculated from original data obtained using sampling intervals of 1 s and 60 s, and those treated by the ONA method, and these compared with the 5 min BC levels that were measured using AE31. The relative deviation between the BC levels measured using these two Aethalometer instruments is defined by:

$$\text{Relative deviation} = \frac{BC_{AE51} - BC_{AE31}}{BC_{AE31}} \quad (3)$$

where BC_{AE51} and BC_{AE31} are the BC concentrations measured by AE51 and AE31, respectively. The Pearson product moment correlation coefficient ($R_{Pearson}$) was applied to determine the relationships between the deviations between the measurements made using these two Aethalometer instruments and the ambient conditions, such as wind speed, temperature, and relative humidity. Throughout the sampling period, the hourly average wind speed was 0.4–1.5 m/s (mean = 0.8 m/s); the hourly average temperature was 15.9–27.6°C (mean = 22.2°C), and the hourly average relative humidity was 55.1–89.1% (mean = 66.9%).

RESULTS AND DISCUSSION

Temporal Variations in BC Levels Measured Using Various Sampling Intervals

Fig. 1 plots the time-variations of BC levels measured using AE51 at sampling intervals of 1 s ((a) and (b)), 60 s ((c) and (d)) and 5 min ((e) and (f)) during a typical 3 h sampling period, and compares them with those measured using AE31 at sampling intervals of 5 min. To realize the influence of BC levels on the measurement results under different BC level conditions, the BC levels were divided into two groups, which were BC levels < 2000 ng/m^3 ((a), (c) and (e)) and > 2000 ng/m^3 ((b), (d) and (f)). AE51 yielded negative measured BC levels at low actual BC levels (Figs. 1(a), (c) and (e)) or at a high time-resolution (Figs. 1(b) and (d)). At a time-resolution of 1 s, the BC levels that were measured by AE51 oscillated greatly between extreme negative and positive values, particularly at BC levels < 2000 ng/m^3. The noise in the measurements made using AE51 may present an erroneously negative BC value at one time point, and an erroneously positive BC value at the next time (or vice versa) more frequently at BC levels < 2000 ng/m^3 than at BC levels > 2000 ng/m^3. The negative values can be eliminated very effectively by the ONA method. However, extreme positive values are still observed after ONA treatment at a time-resolution of 1 s. These extreme positive values could be due to the actual variations of nearby traffic emissions. Furthermore, measurements of 5 min BC levels made concurrently using AE51 and AE31 varied consistently at BC levels > 2000 ng/m^3.

Fig. 2 compares the time-variations of 5 min averaged BC levels measured using AE51 with those measured using AE31 during a typical 3 h sampling period. The 5 min averaged BC levels of AE51 were calculated from original 1 s and 60 s data as well as the same data that were treated by the ONA method. The related noise in the BC data were markedly reduced by 5 min time-averaging of the original data or those treated by the ONA method (Figs. 1(a)–(d) and 2(a)–(d)). However, the oscillating noise in the 5 min averaged BC levels obtained from original data that were measured using AE51 could still be observed at BC levels < 2000 ng/m^3 (Figs. 2(a), (c) and (e)). The BC levels that were measured using AE51 deviated from actual BC levels when a negative value was present, and the real variations of BC levels were lost. Dons *et al.* (2011) demonstrated that 1.5%–2.1% of 5 min BC levels that were measured using an AE51 were negative at BC levels ~1500 ng/m^3. Apte *et al.* (2011) noted that strong sensitivity to mechanical shock and vibration could yield positive and negative excursion in reported BC when using a portable AE51 to monitor BC levels. However, the mechanical shock and vibration were avoided possibly in this study. Nevertheless, the time-variations in 5 min BC levels measured using both the original and the treated data from AE51 were consistent with those measured using AE31 at BC levels > 2000 ng/m^3.

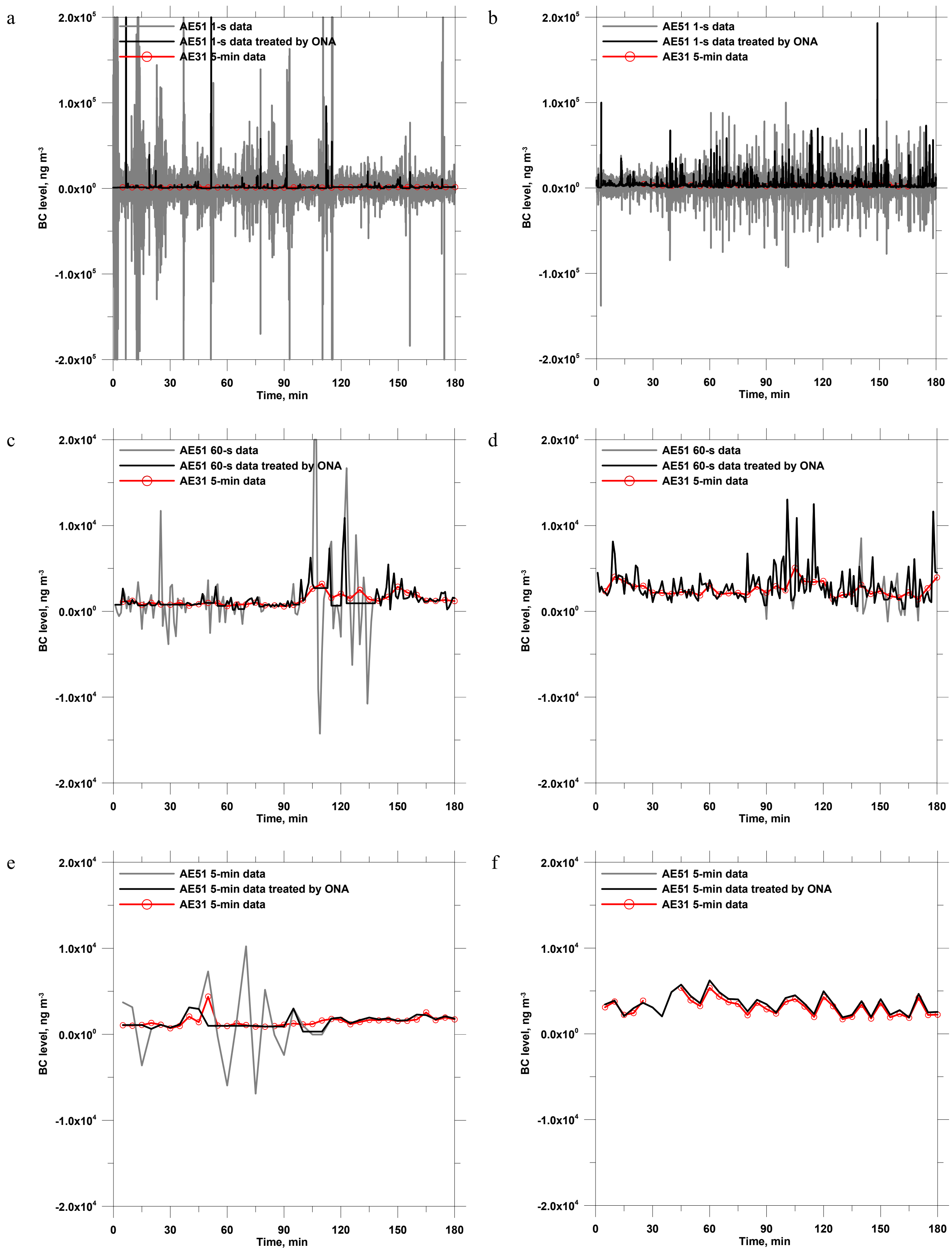


Fig. 1. Time-variations of BC levels measured using AE51 at (a) 1 s, BC levels < 2000 ng/m^3; (b) 1 s, BC levels > 2000 ng/m^3; (c) 60 s, BC levels < 2000 ng/m^3; (d) 60 s, BC levels > 2000 ng/m^3; (e) 5 min, BC levels < 2000 ng/m^3; (f) 5 min, BC levels > 2000 ng/m^3, and AE31 at 5 min.

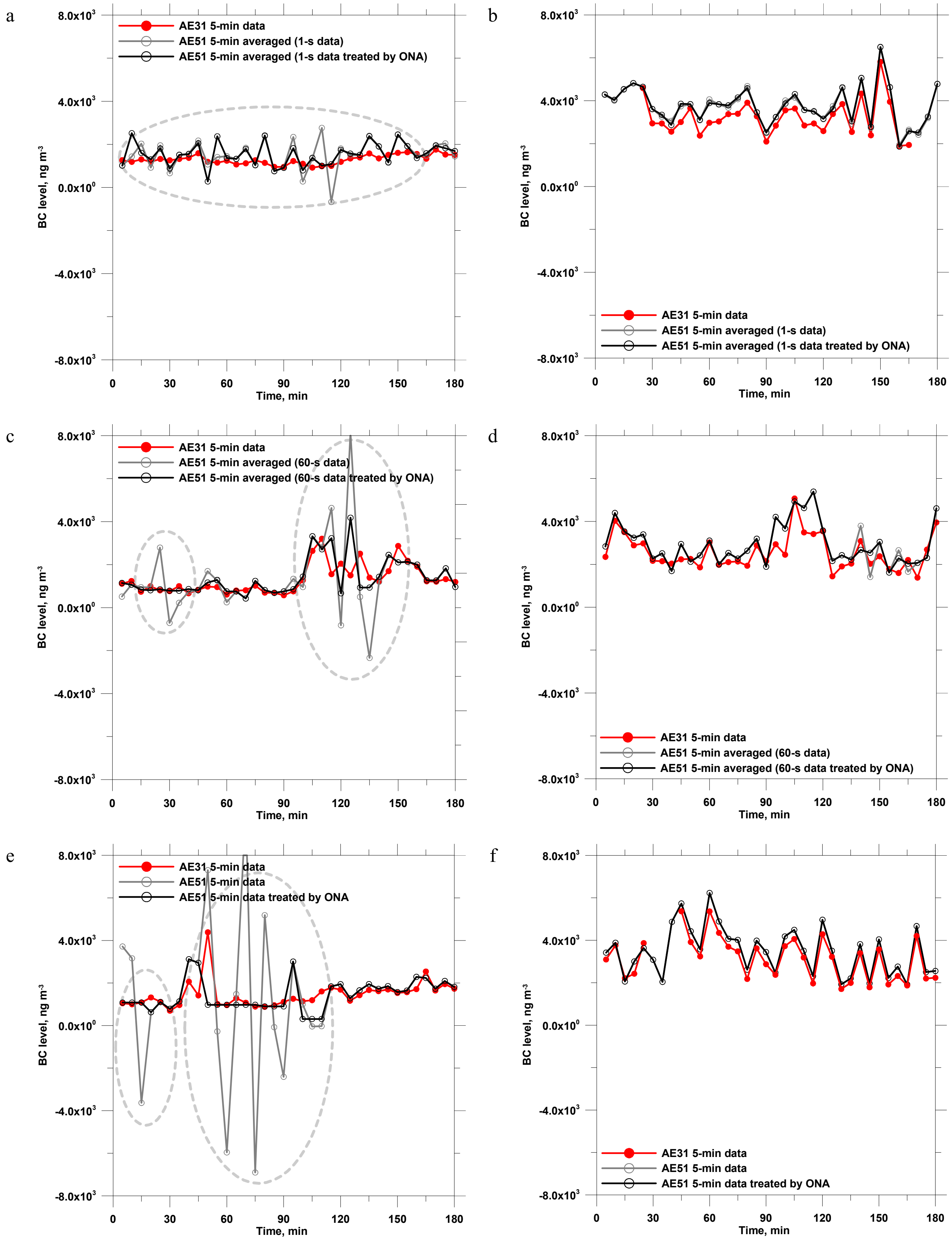


Fig. 2. Time-variations of 5 min averaged BC levels measured using AE51 at (a) 1 s, BC levels < 2000 ng/m^3; (b) 1 s, BC levels > 2000 ng/m^3; (c) 60 s, BC levels < 2000 ng/m^3; (d) 60 s, BC levels > 2000 ng/m^3; (e) 5 min, BC levels < 2000 ng/m^3; (f) 5 min, BC levels > 2000 ng/m^3, and AE31 at 5 min.

Relative Deviations between BC Levels Measured Using AE31 and AE51

Table 2 displays the relative deviations between the 5 min BC levels obtained using AE31 and AE 51. The deviations at sampling intervals of 1 s, 60 s, and 5 min at BC levels < 2000 ng/m^3 were 0.09 ± 0.73, 0.12 ± 0.67, and –0.02 ± 2.10, respectively. The measurements demonstrate that deviations at BC levels < 2000 ng/m^3 exceed those at BC levels > 2000 ng/m^3, and the deviations increased with sampling interval increasing. This relationship follows from the reduction of the noise in the BC level data by time-averaging over 5 min for the shortest sampling interval (1 s). The range of the deviations between the 5 min BC levels measured using these two Aethalometer instruments at BC levels < 2000 ng/m^3 could be narrowed down from 0.08 ± 1.17 to 0.11 ± 0.36 by treating the original data obtained using the AE51 with ONA method. Additionally, the deviations were 0.11 ± 0.16 at BC levels > 2000 ng/m^3. The measurements show that ambient wind speed, temperature, and relative humidity did not significantly affect the deviations ($R_{pearson} = 0.166$, p = 0.251 for wind speed; $R_{pearson} = 0.225$, p = 0.116 for temperature; $R_{pearson} = –0.129$, p = 0.372 for relative humidity).

Aerosol Loading Effects on Measurement Results

Fig. 3 presents the variation in the ratio of 5 min BC levels measured by AE51 to those measured by AE31 with the ATN(AE51). Measurement results clearly demonstrate that the ratio of BC levels measured by AE51 to those measured by AE31 increased with an increased ATN(AE31) at each sampling spot (Fig. 3 spot 1–4). However, the overall ratio of BC levels measured by AE51 to those measured by AE31 decreased as the ATN(AE51) was increased on the same filter ticket of AE51. Measurement results indicate that measured BC levels were affected by aerosol loading on the filter. The BC levels were underestimated proportionally when increasing the ATN value. During the sampling period, the ATN(AE31) rose faster than that of AE51 due to its high aerosol deposition rate. At each sampling spot of AE31, the ratio of BC levels measured by AE51 to those measured by AE31 clearly increased with an increasing ATN(AE31), owing to that the BC levels measured by AE31 were more significantly underestimated than those measured by AE51.

Various correction schemes have been published for Aethalometer taking into account the loading effect (Weingartner *et al.*, 2003; Arnott *et al.*, 2005; Schmid *et al.*, 2006; Virkkula *et al.*, 2007). Virkkula *et al.* (2007) developed a simple procedure for correcting the loading effects of Aethalometer data. Here, this simple correction algorithm was adopted, and the correction equation can be expressed as:

$$BC_{corredted} = [1 + k\cdot(ATN - ATN_0)]\cdot BC_{measured} \quad (4)$$

where $BC_{corrected}$ and $BC_{measured}$ are the corrected BC level with loading effect and measured BC level, respectively, in ng/m^3; ATN_0 is the initial ATN of each sampling spot (ATN ≥ ATN_0); k is the correcting factor in this algorithm, which is obtained from the regression of BC level on ATN. When the filter was clean, the Aethalometer data could be assumed to be true. The measured BC levels can be normalized by over the reference BC levels at different ATN values, for use to observe the aerosol loading effects during a sampling spot. In this study, the BC level measured by AE51 could be treated as a reference value when the loading effect was minimal at a low ATN. Fig. 4 shows the variation in the ratio of 5 min BC levels measured by AE31 to those measured by AE51 with the ATN(AE31). Analytical results clearly demonstrate that the normalized BC levels for AE31 (ratio of BC levels measured by AE31 to those measured by AE51) had the same decreasing trend for spots 1 and 2 when ATN(AE51) was low. Therefore, the correcting factor, k, could be evaluated according to the decreasing slop of the regression line in Fig. 4. According to those results, the correcting factor for AE31 was 0.0033 when used to measure the BC levels at a traffic site. Virkkula *et al.* (2007) demonstrated that the correcting factor in the subway tunnel was 0.0051. Park *et al.* (2010) suggested that correcting factors for the indoor office, residential living room, and

Table 2. Relative deviations between the 5 min BC levels obtained using AE31 and AE51.

	AE31 BC level < 2000 ng/m^3					AE31 BC level > 2000 ng/m^3				
	N[a]	Mean	S.D.[b]	Median	Q_1–Q_3[c]	N	Mean	S.D.	Median	Q_1–Q_3
Original data										
AE51 1 s data	76	0.09	0.73	0.09	–0.16–0.37	147	0.12	0.10	0.11	0.05–0.19
AE51 60 s data	136	0.12	0.67	0.09	–0.07–0.29	151	0.07	0.22	0.09	0.01–0.14
AE51 5 min data	64	–0.02	2.10	0.13	0.03–0.27	184	0.15	0.14	0.14	0.06–0.23
AE51 all data	276	0.08	1.17	0.11	–0.06–0.30	482	0.11	0.16	0.11	0.04–0.20
Data treated by ONA										
AE51 1 s data	76	0.08	0.37	0.09	–0.12–0.25	147	0.12	0.10	0.12	0.05–0.19
AE51 60 s data	136	0.13	0.34	0.10	–0.05–0.25	151	0.07	0.17	0.08	0.00–0.14
AE51 5 min data	64	0.08	0.38	0.09	0.02–0.23	184	0.14	0.15	0.14	0.06–0.23
AE51 all data	276	0.11	0.36	0.09	–0.04–0.25	482	0.11	0.15	0.11	0.04–0.20

[a] Observation number (5 min interval)
[b] Standard deviation
[c] First quartile value–Third quartile value

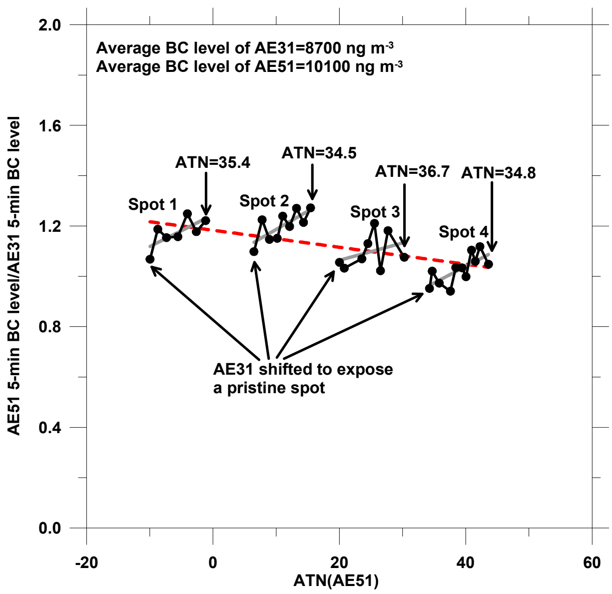


Fig. 3. Variation in the ratio of 5 min BC levels measured by AE51 to those measured by AE31 with the ATN(AE51).

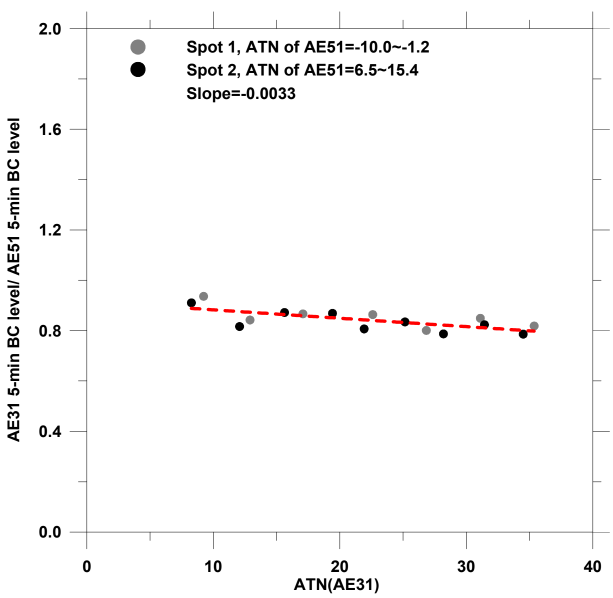


Fig. 4. Variation in the ratio of 5 min BC levels measured by AE31 to those measured by AE51 with the ATN(AE31).

urban site were 0.0042, 0.0024, and 0.0028, respectively. Wang *et al.* (2011) suggested that correcting factors were 0.0068, 0.0017, 0.0062, and 0.0081 for spring, summer, fall, and winter, respectively, when AE42 used to measure the BC levels in East Rochester, New York, US.

The corrected BC levels obtained by AE31 were evaluated based on Eq. (3) with k = 0.0033. These corrected BC levels obtained by AE31 were then treated as reference BC levels. Fig. 5(a) presents the variation in the ratio of 5 min BC levels measured by AE51 to 5 min corrected BC levels obtained by AE31 with the ATN(AE51). The overall normalized BC levels for AE51 (ratio of BC levels measured by AE51 to corrected BC levels obtained by AE31) decreased as the ATN(AE51) increased on the same filter ticket of AE51. Again, the correcting factor for AE51 could be evaluated from the decreasing slope of the regression line in Fig. 5(a); it was 0.0039 when AE51 was used to measure the BC levels at this traffic site. Analytical results indicate that the BC levels could be underestimated by up to 15% when the ATN value rose to ~40. Based on these two correcting factors for AE31 and AE51, the overall ratio of corrected BC levels obtained by AE51 to the corrected BC levels obtained by AE31 could keep as a constant with an increasing ATN(AE51) (Fig. 5(b)). Above results suggest that loading effects on BC levels can be post-corrected very effectively by the proposed method.

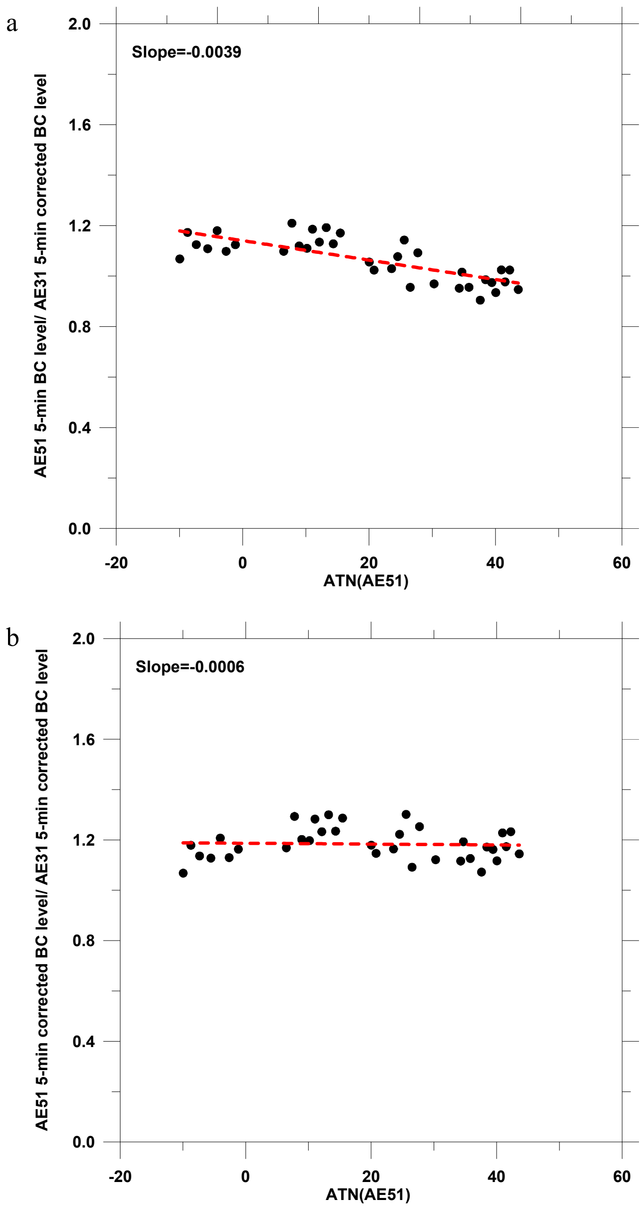


Fig. 5. Variation in (a) the ratio of 5 min BC levels measured by AE51 to 5 min corrected BC levels obtained by AE31 with the ATN(AE51) and (b) the ratio of 5 min corrected BC levels obtained by AE51 to 5 min corrected BC levels obtained by AE31 with the ATN(AE51).

Relationships between 5 min BC Levels Measured Using AE31 and AE51

Figs. 6(a)–(b) presents the relationships between the 5 min BC levels measured using AE31 and AE51 over the whole sampling period, obtained from the original data and from the data that were treated by the ONA method. The measurements show that the 5 min BC levels measured using AE51 were higher than those measured using AE31 by approximately 13% (R^2 = 0.966) and 11% (R^2 = 0.982) for original data and data treated by ONA, respectively. The BC data that were measured by AE51 should be post-processed to eliminate the extreme negative and positive values when sampling noise is present. They then agree very closely with those measured using AE31. Fig. 6(c) presents the relationships between the 5 min corrected BC levels obtained using AE31 and AE51 over the whole sampling period from AE51 data that were treated by the ONA method. The 5 min corrected BC levels obtained by AE51 exceeded those obtained by AE31 by approximately 14% (R^2 = 0.991). The differences between the measurements made using these two Aethalometer instruments may have been caused by the different aerosol sampling flow rates, sample spot areas, filter materials, and mass attenuation cross-section parameters (σ_{ATN}) of the two Aethalometer instruments. The default value of the σ_{ATN} for AE31 is approximately 1.3 times that of AE51. The aerosol deposition velocity (filter face velocity) through the filter of AE31 is approximately 2.6 times that of AE51. This denser deposition of aerosols may have resulted in lower light transmission through the aerosol-laden filter. Therefore, the BC levels that were measured by AE31 were reasonably lower than those measured by AE51 since the σ_{ATN} value and aerosol deposition velocity of AE31 were higher than those of AE51.

Available information about the performance of AE51 is limited. Babu *et al.* (2011) reported that BC levels that

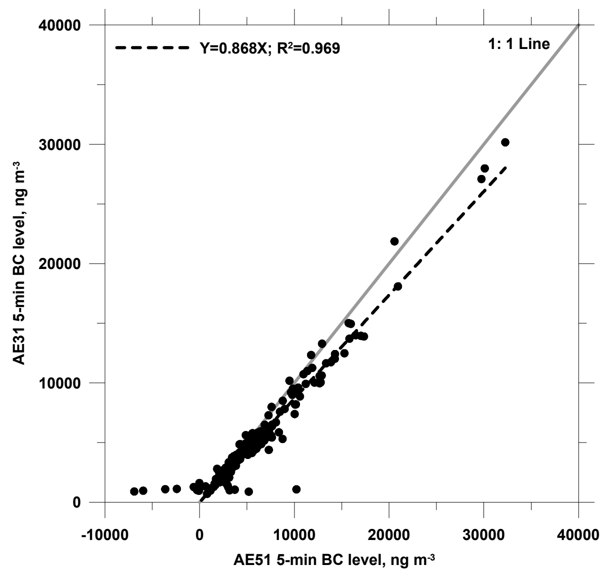
a


Fig. 6. Relationships between 5 min BC levels measured using AE31 and AE51 over whole sampling period: (a) original data and (b) data treated by ONA method (c) corrected data.

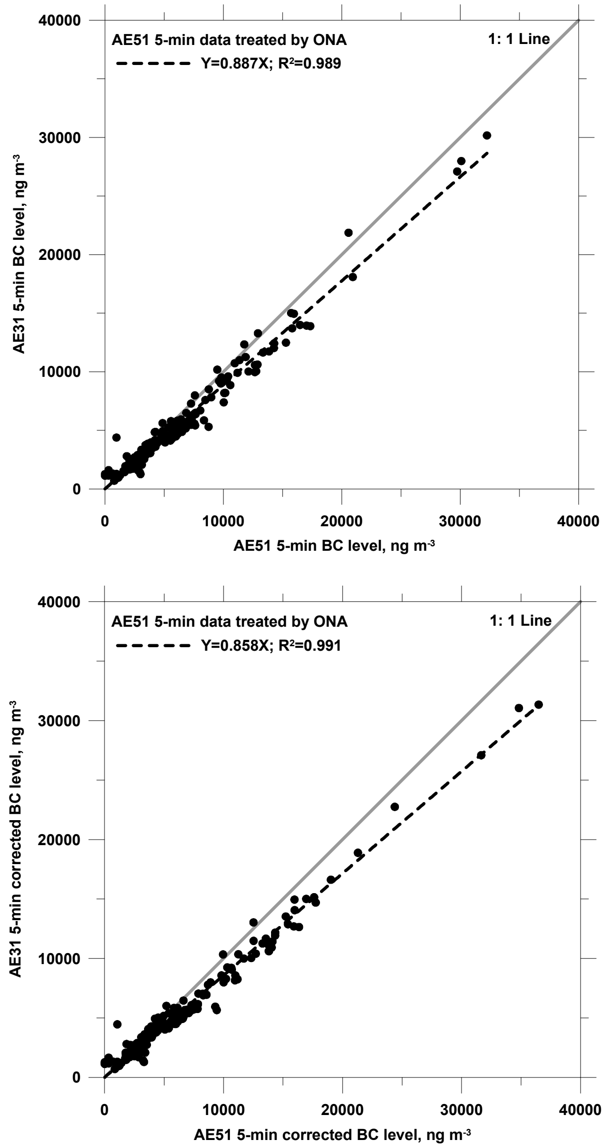
b
c


Fig. 6. *(continued).*

were measured by AE51 were approximately 13% lower than those measured by AE31 when BC levels < 3000 ng/m^3. The range of measured BC levels (up to 35000 ng/m^3) in this study was significantly larger than that of those measured by Babu *et al.* (2011) (BC levels < 3000 ng/m^3). Unfortunately, Babu *et al.* (2011) did not present detailed information about the measurement conditions.

CONCLUSIONS

Negative BC levels may be present using AE51 at low actual BC levels or at a high time-resolution. The negative values can be eliminated very effectively by the ONA method. The time-variation of the 5 min BC levels measured using AE51 are highly consistent with those measured using AE31. The extent to which loading affects the measurement results of BC levels can be observed during the sampling period. This study also evaluates the correcting factor, *k*. The correcting factors are approximately 0.003–

0.004 for AE31 and AE51 when used for monitoring the BC levels at this traffic site. However, these k factors are site and season specific. Analytical results indicate that the BC levels can be underestimated by up to 15% when the ATN value increases to ~40. Measurements results demonstrate that the BC levels measured by AE51 are higher than that those measured by AE31 by approximately 14%. This difference may be owing to the different aerosol sampling flow rates, sample spot areas, filter materials, and mass attenuation cross-section parameters (σ_{ATN}) of the two instruments.

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