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An evaluation of three methods for measuring black carbon in Alert, Canada

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Calculation of the Aerosol Angstrom Absorption Exponent:

The aerosol Ångström absorption exponent (AAE) was calculated from the PSAP absorption measurements. The AAE is defined as

$$AAE = \frac{\ln(\frac{\sigma ap(\lambda_1)}{\sigma ap(\lambda_2)}}{\ln(\frac{(\lambda_1}{\lambda_2})} \qquad \text{(S1)}$$

where λ_1=467 nm and λ_2=660 nm and $\sigma_{ap}(\lambda_1)$ is the absorption at 467 nm and $\sigma_{ap}(\lambda_2)$ is the absorption at 660 nm.

Uncertainty in AAE

Standard techniques were applied to determine the combined uncertainties in the Aerosol Absorption Exponent calculated at two wavelengths; λ_1=467 nm and λ_2=660 nm. The uncertainty in AAE is determined by Eq. S2 and has also been used in Sherman et al. (2015).

$$\Delta AAE\left(\frac{467nm}{660nm}\right) = ((\frac{\partial AAE}{\partial \sigma_{ap,467}})^2 \Delta {\sigma_{ap,467}}^2 + (\frac{\partial AAE}{\partial \sigma_{ap,660}})^2 \Delta {\sigma_{ap,660}}^2 + 2 * corr(\sigma_{ap,467}, \sigma_{ap,660}) * \left(\frac{\partial AAE}{\partial \sigma_{ap,467}}\right) * \left(\frac{\partial AAE}{\partial \sigma_{ap,660}}\right) * \Delta\sigma_{ap,467} * \Delta\sigma_{ap,660}))^{1/2} \qquad \text{(S2)}$$

where

$$\left(\frac{\partial AAE}{\partial \sigma_{ap,467}}\right) = \frac{2.26}{\sigma_{ap,467}} \; and \; \left(\frac{\partial AAE}{\partial \sigma_{ap,660}}\right) = \frac{-2.26}{\sigma_{ap,660}}$$

The time series of hourly light absorption measurements from the PSAP at Alert at 550 nm wavelength is shown in Fig S1a. The light absorption has been corrected according to Bond et al. (1999) and also Ogren (2010) for loading and scattering interferences. Episodic increases in the absorption during winter/spring reach as high as 4 Mm^{-1} and overall lower values are measured during the summer and fall. Dust and brown carbon each have strong wavelength dependences, but BC does not. The impact of non-BC light absorbing species will appear as deviations from near unity (1.1±0.3) in the Ångstrom Absorption exponent (AAE) if the non-BC light absorbing species make up more than 40% of the BC (Lack and Langridge, 2013). At Alert, non-BC light absorbing species may include brown carbon and dust. At Alert, absorbing OC

(POC, i.e., brown carbon) is more than 40% of the total absorbing carbon for most of the time. The hourly averaged AAE values between March 2011 and December 2013 are shown in Fig S1b. Values of AAE between 0.5 and 1.5 represent the absorption primarily due to fossil fuel BC. A value near 1.0 is considered to be an example of graphitic carbon particles (Petzold et al., 2009), values between 1 and 1.5 are due to total carbon, while AAE values close to 0.5 may reflect different absorption characteristics of pure elemental carbon and increase with varying amounts of OC (Bahadur et al., 2012). There are brief episodic increases in the AAE where values over two are reached, indicating the presence of non-BC absorbing aerosol, but most of the fine mode absorption measurements fall within 0.5-1.5, suggesting that EBC is the primary absorbing component with episodic influences of non-BC absorbing components. Mineral dust gives AAE values of three and larger at visible wavelengths (Petzold et al., 2009), which are not evident in Supplemental_Fig1b.

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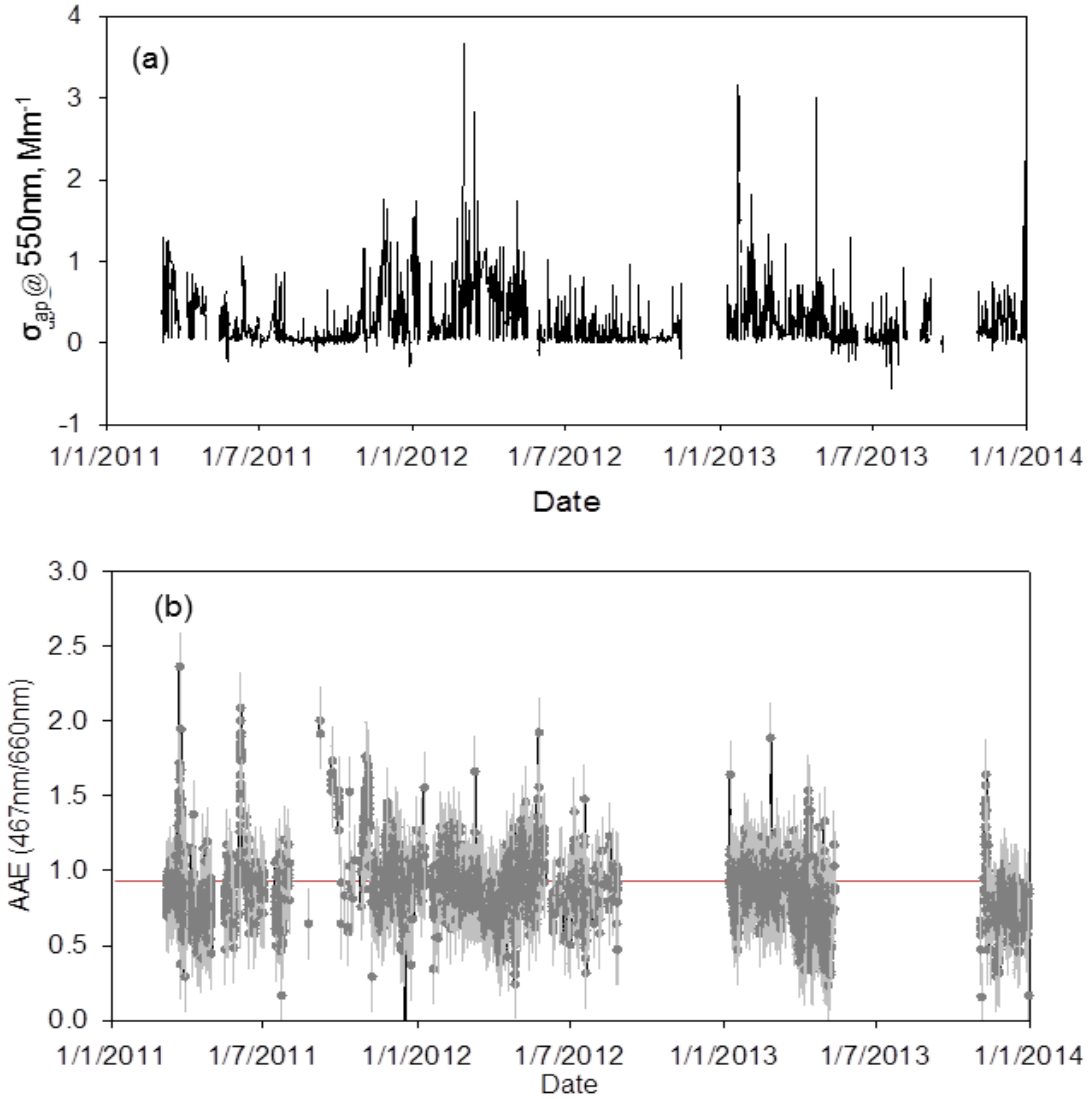

Figure S1: (a) Hourly aerosol light absorption measurements, σ_{ap}, at 550 nm at Alert; (b) hourly averaged Aerosol Angstrom Exponent (AAE) with uncertainty (light gray) calculated from $AAE=-\ln(\sigma_{ap}(\lambda_1)/\sigma_{ap}(\lambda_2))/\ln(\lambda_1/\lambda_2)$ where λ_1=467 nm and λ_2=660 nm and $\sigma_{ap}(\lambda_1)$ is absorption at 467 nm and $\sigma_{ap}(\lambda_2)$ is absorption at 660 nm. A value of AAE=1 is for graphite aerosol.

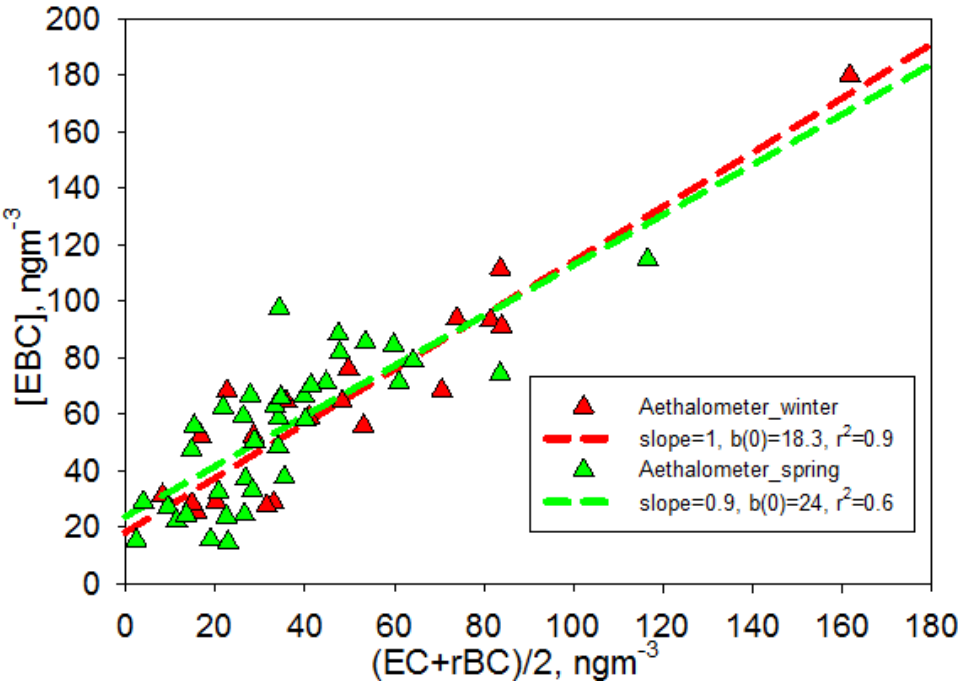

Figure S2: Improved agreements were obtained between the best estimated black carbon mass and masses obtained by an optical technique such as the Aethalometer (green and red triangles are for data during the spring and winter). EBC Aethlaometer and rBC data were averaged to EC sampling times.

Monthly averages and standard deviations for EBC, σap, rBC, EC

Year	month	EBC_mean	EBC_std dev	σap_mean	σap_std dev	rBC_mean	rBC_std dev	EC_mean	EC_std dev
		Aethalometer	Aethalometer	PSAP	PSAP	SP2	SP2	Thermal	Thermal
		ngm-3	ngm-3	Mm-1	Mm-1	ngm-3	ngm-3	ngm-3	ngm-3
2011	3	74	32	0.65	0.29	49	26	48	39
2011	4	58	21	0.48	0.11	29	11	41	8
2011	5	22	19	0.18	0.16	12	7	28	12
2011	6	21	21	0.20	0.19	10	11	34	21
2011	7	12	18	0.12	0.14	7	9	29	19
2011	8	4	6	0.05	0.05	3	6	21	17
2011	9	6	14	0.05	0.09	1	4	4	5
2011	10	10	14	0.08	0.11	3	4	7	7
2011	11	52	43	0.43	0.39	27	26	25	37
2011	12	49	39	0.31	0.35	38	35	65	23
2012	1	53	50	0.47	0.44	40	41	36	16
2012	2	45	36	0.38	0.30	33	30	40	52
2012	3	89	54	0.76	0.46	58	35	93	40
2012	4	69	23	0.58	0.16	27	10	48	17
2012	5	54	34	0.50	0.31	19	12	46	11
2012	6	11	15	0.08	0.11	5	8	24	10
2012	7	15	19	0.12	0.13	9	15	23	28
2012	8	12	16	0.08	0.09	5	7	14	11
2012	9	15	25	0.09	0.11	4	9	17	10
2012	10	10	14	0.06	0.04	3	8	9	7
2012	11	27	23	0.12	0.14	12	13	22	23
2012	12	9	12	-999.00	-999.00	11	12	10	10
2013	1	85	81	0.63	0.67	44	50	72	91
2013	2	73	45	0.53	0.33	39	25	77	24
2013	3	40	28	0.28	0.18	17	15	34	24
2013	4	61	32	0.36	0.11	22	15	33	14
2013	5	30	21	0.12	0.15	9	7	13	7
2013	6	12	18	0.06	0.10	3	6	3	3
2013	7	12	24	0.04	0.06	6	13	10	6
2013	8	6	10	0.13	0.20	2	4	4	4
2013	9	11	31	0.25	0.29	1	3	10	13
2013	10	14	25	-999.00	-999.00	5	9	11	9
2013	11	36	26	0.19	0.11	16	10	22	27
2013	12	55	45	0.36	0.32	32	28	37	23

Read me for datafile named Alert_Monthly_EBC_EC_rBC_babs

The data-set contains averages of monthly data and the columns have the following headers:

Column	Description
A	Year
B	Month
C	EBC_mean Aethalometer concentration, 880 nm (ng m^{-3})
D	EBC_std dev Aethalometer concentration, 880 nm (ng m^{-3})
E	bap_mean PSAP – monthly averaged aerosol light absorption coefficient at 550 nm measured by Particle Soot Absorption Photometer (PSAP)
F	bap_std dev PSAP – std dev in monthly averaged aerosol light absorption coefficient at 550 nm measured by Particle Soot Absorption Photometer (PSAP)
G	rBC_mean SP2 (ngm^{-3}) – monthly averaged refractory black carbon (rBC) concentrations measured by Single Particle Soot Photometer (SP2)
H	rBC_std dev SP2 (ngm^{-3}) – standard deviation in monthly averaged refractory black carbon concentrations measured by Single Particle Soot Photometer (SP2)
I	EC_mean Thermal method (ngm^{-3}) – monthly averaged elemental carbon concentrations as measured by the Thermal method.
J	EC_std dev Thermal method (ngm^{-3}) – standard deviation in monthly averaged elemental carbon concentrations as measured by the Thermal method.