On-line training event on equivalent Black Carbon (eBC)

Determination of equivalent BC mass concentration from filter absorption photometers (FAPs)

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In brief:

- "BC" cannot be measured
- There are no standardised methods for black carbon (BC).
- Its concentration is indirectly derived from the measurements of light absorption (from this "black") using FAPs (e.g. Aethalometers, MAAP)
- The absorption from FAPs is converted into "BC" mass concentration mathematically using one predefined constant term (MAC_{BC}) used to convert absorption into a mass concentration
- MAC_{BC} was initially obtained comparing optical and thermal measurements of filters loaded with refractory carbonaceous material (BC) used as reference.
- BC is a mass concentration equivalent to the mass of the reference BC material needed to explain the measured absorption.

Definitions:

14) "**black carbon**" or "**BC**" means carbonaceous aerosols measured by light absorption;

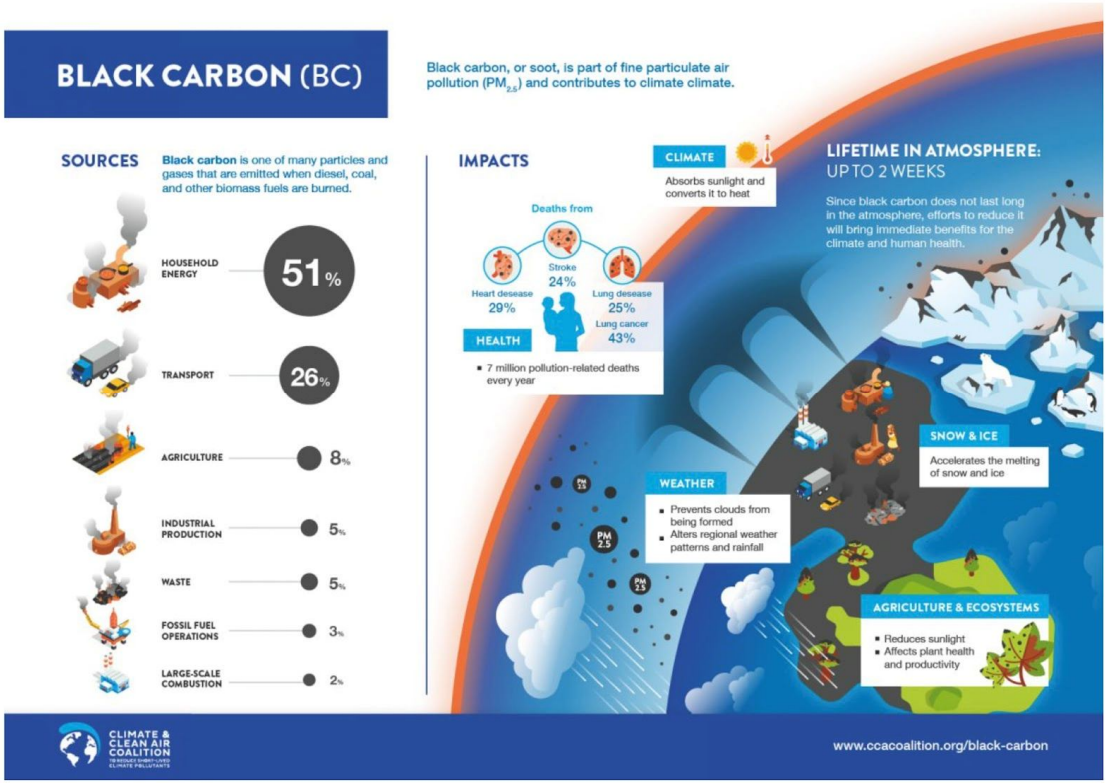


In brief:

- The correct terminology is “equivalent black carbon (eBC)”
- “equivalent” and “equivalence” are two different things
- For demonstrating the equivalence of a candidate method (e.g. the Beta-gauge technique) with the reference (gravimetric) method, it is allowed to establish first a site and time dependent calibration factor.
- Using site and time dependent MAC_{BC} values would very probably make it possible to demonstrate the equivalence between FAP techniques and the CEN standard method (EN16909) for determining EC.

DEFINITION OF BLACK CARBON (BC)

- Black Carbon (BC), or elemental carbon (EC), is a product of incomplete combustion of carbon-based fuels (vehicles, wood and biomass burning, open burnings, industrial emissions, shipping, aviation,.....)



ACTRIS RI URBANS European Commission CAIS ECAC

DEFINITION OF BLACK CARBON (BC)

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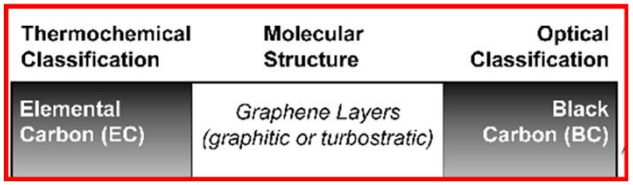


- Refractory (vapor. temp. 4000 ºK)
- Unsoluble in water and organic solvents
- Graphitic SP^2-bonded carbon atoms
- Strong absorption efficiency in the whole solar spectrum

DEFINITION OF BLACK CARBON (BC)

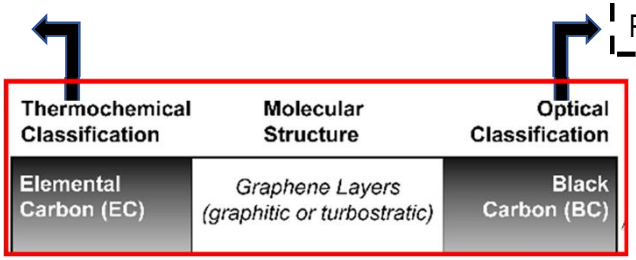
- Black Carbon (BC), or elemental carbon (EC), is a product of incomplete combustion of carbon-based fuels (vehicles, wood and biomass burning, open burnings, industrial emissions, shipping, aviation,.....)

BC and **EC** are distinguished by the measurement methods

The EN 16909 standard method for determining EC

EC is determined by heating to high temperature the sample (PM) in presence of oxygen (for combustion) to determine the amount of pure carbon present. EC refers to carbon in its pure, elemental form.

A reference technique for measuring the mass concentration of EC exists



FAPs (filter absorption photometers; AE33, AE36, MAAP)

BC is indirectly derived through methods (FAPs) that measure the particle light absorption, assuming that BC is the unique absorbing species.

There is no method for measuring “BC” mass concentration at all

DETERMINATION OF EQUIVALENT BLACK CARBON (eBC) MASS CONCENTRATION: TERMINOLOGY

FAPs (filter absorption photometers; Aethalometers, MAAP) provide the light absorption coefficient [$\boldsymbol{b_{ABS}(\lambda)}$] that is used to **derive** the BC mass concentration

$$\boldsymbol{BC = \frac{b_{Abs}}{MAC_{BC}}} \qquad \left[\frac{\mu g}{m^3}\right] = \frac{[Mm^{-1}]}{\left[\frac{m^2}{g}\right]}$$

The softwares of FAPs apply a constant **MAC_{BC}** to derive BC.

MAC_{BC} obtained initially by comparing optical and thermal measurements of filters loaded with refractory carbonaceous material used as reference.

DETERMINATION OF EQUIVALENT BLACK CARBON (eBC) MASS CONCENTRATION: TERMINOLOGY

FAPs (filter absorption photometers; Aethalometers, MAAP) provide the light absorption coefficient [$b_{ABS}(\lambda)$] that is used to **derive** the BC mass concentration

$$eBC = \frac{b_{Abs}}{MAC_{BC}} \qquad \left[\frac{\mu g}{m^3}\right] = \frac{[Mm^{-1}]}{\left[\frac{m^2}{g}\right]}$$

eBC
= mass concentration of the reference BC material (that was used to estimate the MACBC) needed to explain the measured absorption

- eBC is for particle light absorption the same as "CO_2-eq" is for Global Warming Potential. CO_2-eq is a metric measure that converts amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential as these other gases.

DETERMINATION OF EQUIVALENT BLACK CARBON (eBC) MASS CONCENTRATION: TERMINOLOGY

FAPs (filter absorption photometers; Aethalometers, MAAP) provide the light absorption coefficient [$b_{ABS}(\lambda)$] that is used to **derive** the BC mass concentration

$$eBC = \frac{b_{Abs}}{MAC_{BC}}$$

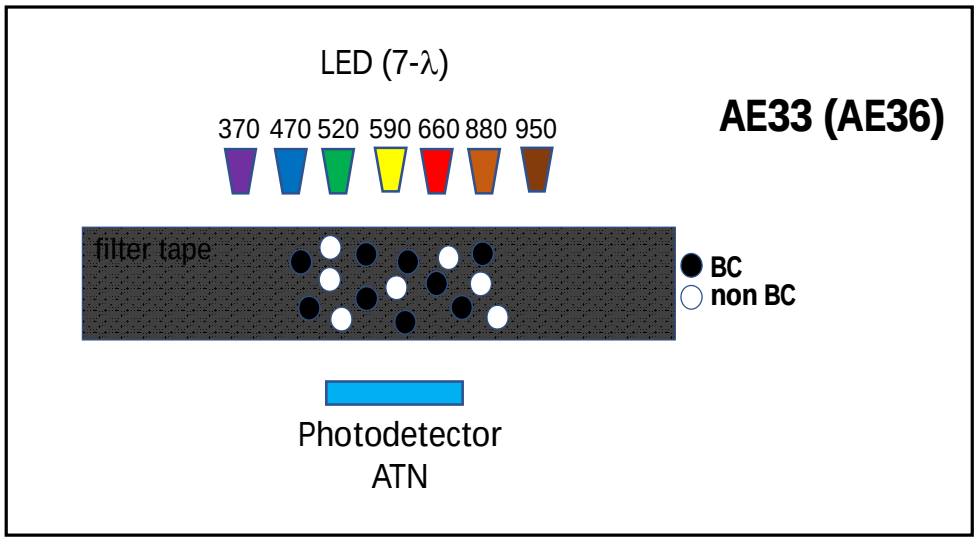
Petzold et al. (2013)

"Equivalent black carbon (eBC) should be used instead of black carbon for data derived from optical absorption methods, together with a suitable MAC for the conversion of light absorption coefficient into mass concentration. ….. When reporting eBC, i.e., mass concentration, it is crucial to identify the MAC value used for the conversion…"

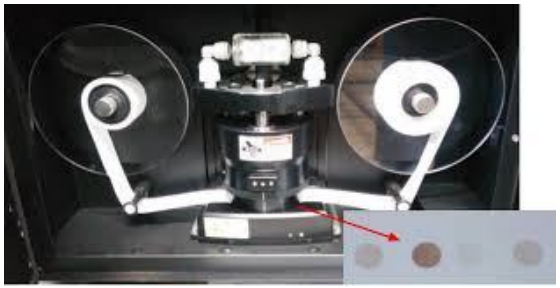
DETERMINATION OF EQUIVALENT BLACK CARBON (eBC) MASS CONCENTRATION

Aethalometers

$$eBC = \frac{b_{Abs}}{MAC_{BC}}$$



Aethalometers are based on illuminating with LED lights a filter tape where PM is deposited and measuring the attenuation of the light.



Two artifacts:

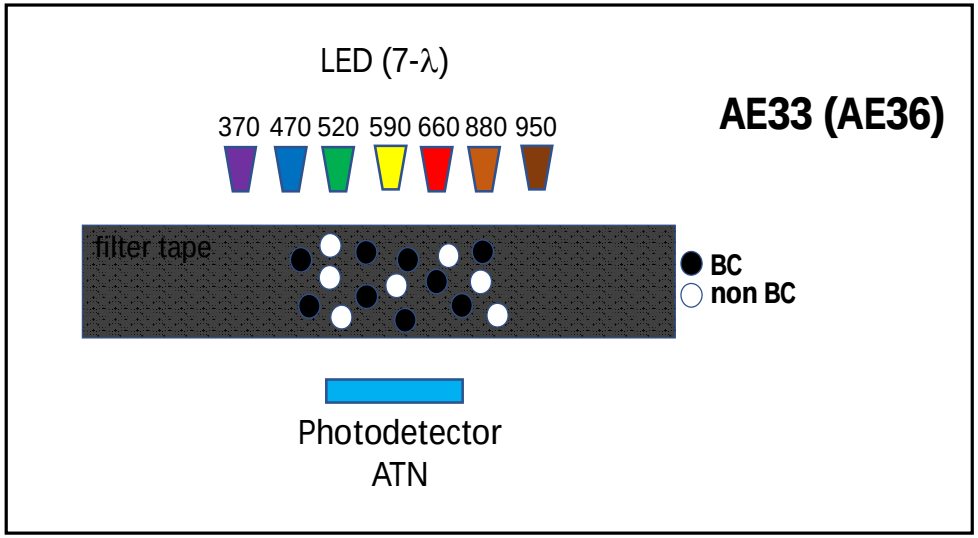
- Factor loading; Dual-spot technology (Drinovec et al., 2015)

- Optical enhancement factor (multiple-scattering factor)

DETERMINATION OF EQUIVALENT BLACK CARBON (eBC) MASS CONCENTRATION

Aethalometers

$$eBC = \frac{b_{Abs}}{MAC_{BC}}$$



$$b_{ATN} = b_{ABS} + b_{SCAT,(PM+filter)}$$

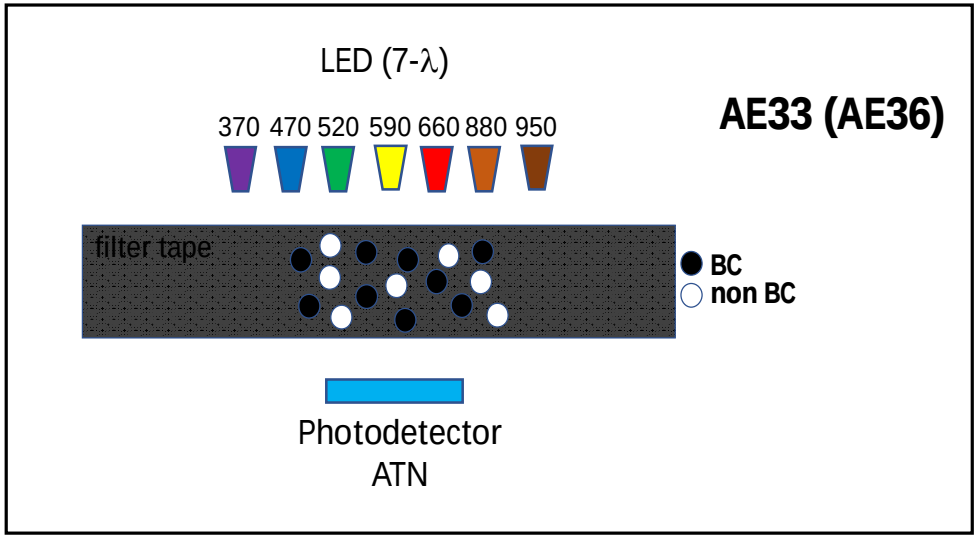
Artifact (C)

- Optical enhancement factor (multiple-scattering factor (C))

DETERMINATION OF EQUIVALENT BLACK CARBON (eBC) MASS CONCENTRATION

Aethalometers

$$eBC = \frac{b_{Abs}}{MAC_{BC}}$$



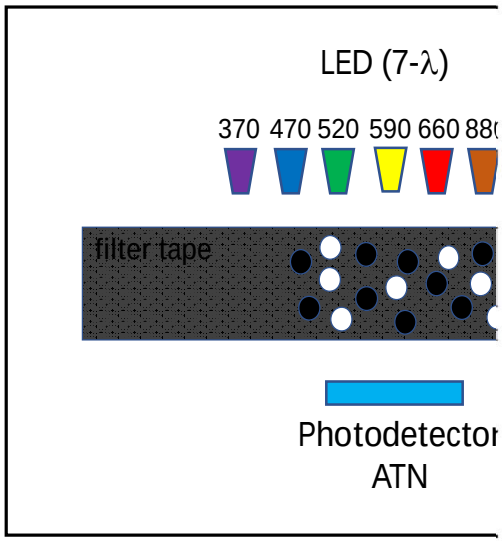
$$b_{ABS} = \frac{b_{ATN}}{C}$$

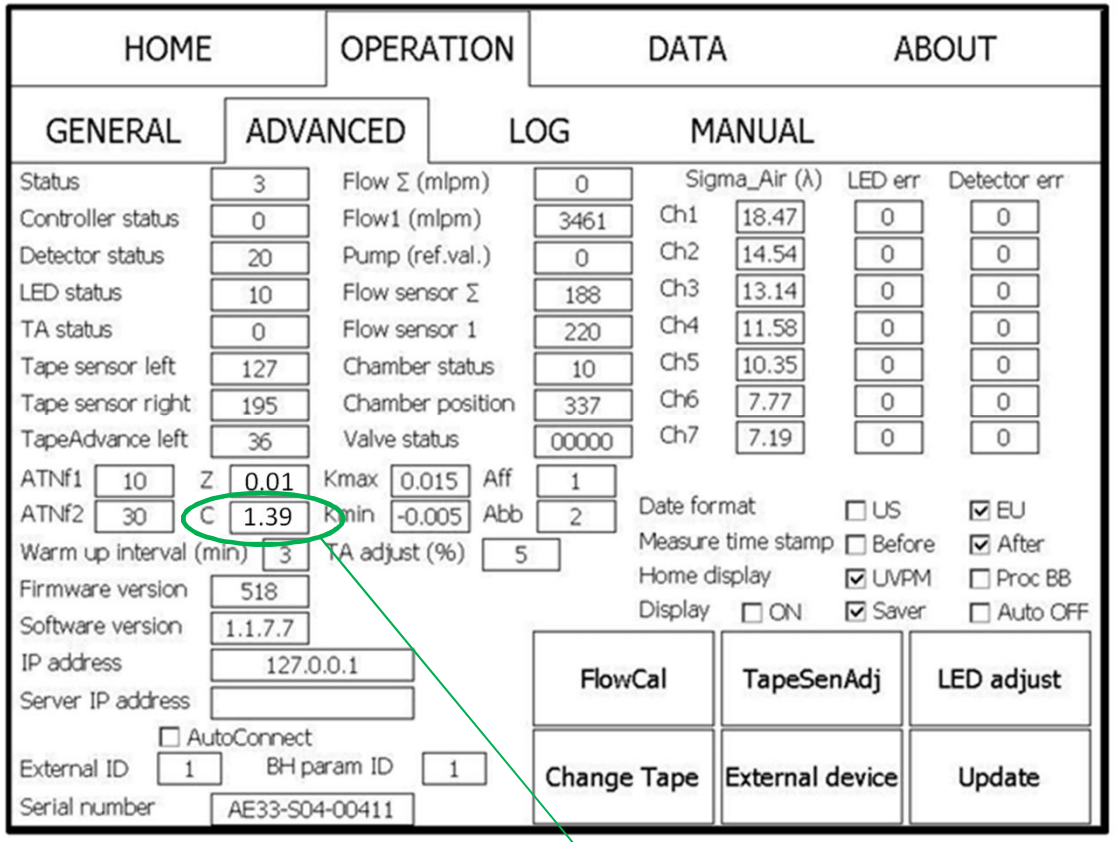
- Optical enhancement factor (multiple-scattering factor (C))

DETERMINATION OF EQUIVALENT BLACK CARBON (eBC) MASS CONCENTRATION

Aethalometers

$$eBC = \frac{b_{Abs}}{MAC_{BC}}$$





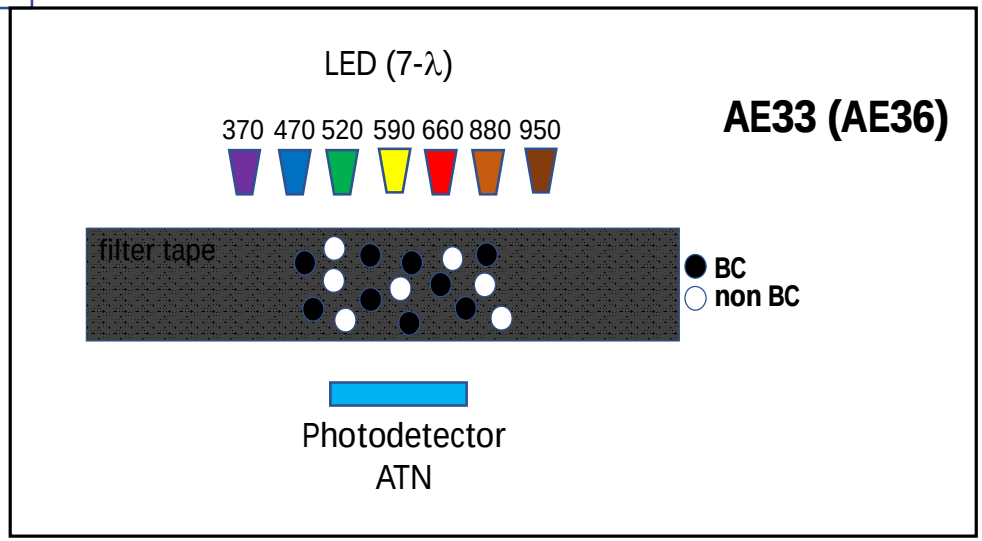
$$b_{ABS} = \frac{b_{ATN}}{C}$$

M8060 recommended filter tape

DETERMINATION OF EQUIVALENT BLACK CARBON (eBC) MASS CONCENTRATION

Aethalometers

$$eBC\ (\lambda) = \frac{b_{Abs}(\lambda)}{MAC_{BC}(\lambda)}$$

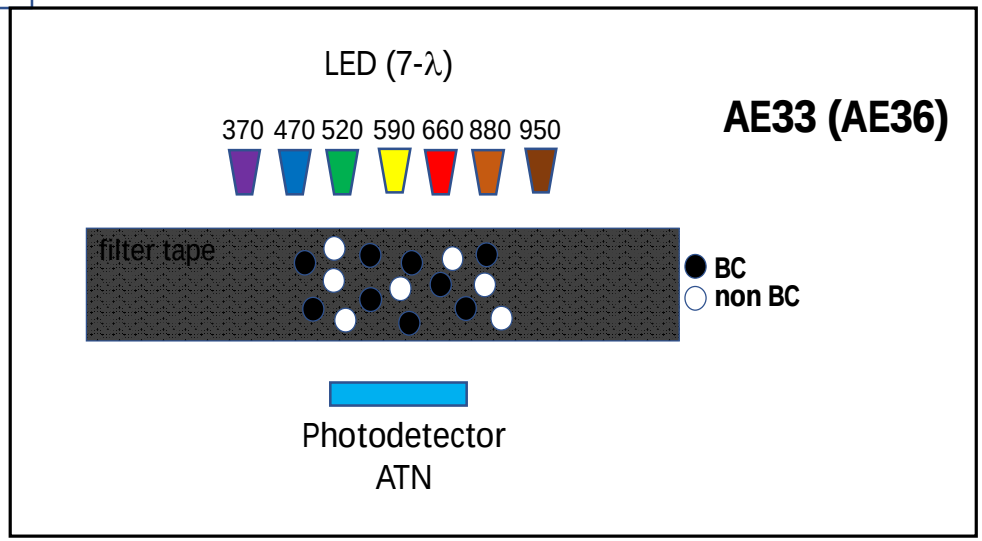


$$b_{ABS}(\lambda) = \frac{b_{ATN}(\lambda)}{1.39}$$

DETERMINATION OF EQUIVALENT BLACK CARBON (eBC) MASS CONCENTRATION

Aethalometers

$$eBC\ (\lambda) = \frac{b_{Abs}(\lambda)}{MAC_{BC}(\lambda)}$$



AE33 setup file

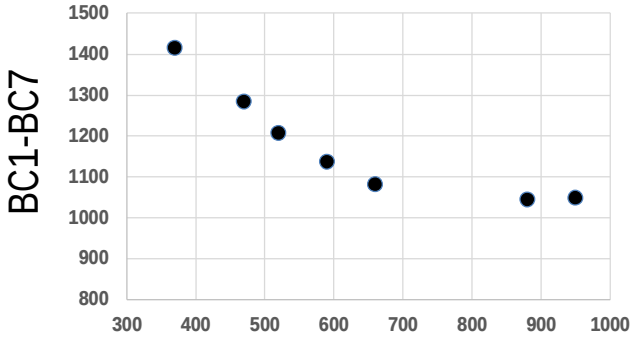
	`<!-- sigma value for channel 1 -->`
MAC_{BC} (370)	`<SG1>18.47</SG1>`
	`<!-- sigma value for channel 2 -->`
MAC_{BC} (470)	`<SG2>14.54</SG2>`
	`<!-- sigma value for channel 3 -->`
MAC_{BC} (520)	`<SG3>13.14</SG3>`
	`<!-- sigma value for channel 4 -->`
MAC_{BC} (590)	`<SG4>11.58</SG4>`
	`<!-- sigma value for channel 5 -->`
MAC_{BC} (660)	`<SG5>10.35</SG5>`
	`<!-- sigma value for channel 6 -->`
MAC_{BC} (880)	`<SG6>7.77</SG6>`
	`<!-- sigma value for channel 7 -->`
MAC_{BC} (950)	`<SG7>7.19</SG7>`

$$b_{ABS}(\lambda) = \frac{b_{ATN}(\lambda)}{1.39}$$

DETERMINATION OF EQUIVALENT BLACK CARBON (eBC) MASS CONCENTRATION

Aethalometers

$$eBC\ (\lambda) = \frac{b_{Abs}(\lambda)}{MAC_{BC}(\lambda)}$$



AE33 example file

AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG
		ng/m3			ng/m3			ng/m3			ng/m3			ng/m3			ng/m3			ng/m3
1104	1228	**1415**	1042	1131	**1285**	1009	1076	**1208**	972	1023	**1138**	951	985	**1082**	963	969	**1045**	967	972	**1049**
	MAC,BC	**18.47**			**15.54**			**13.14**			**11.58**			**10.35**			**7.77**			**7.19**
	wavelength	**370 nm**			**470 nm**			**520 nm**			**590 nm**			**660 nm**			**880 nm**			**950 nm**
SPOT 1	SPOT 2		SPOT 1	SPOT 2		SPOT 1	SPOT 2		SPOT 1	SPOT 2		SPOT 1	SPOT 2		SPOT 1	SPOT 2		SPOT 1	SPOT 2	
BC11	BC12	**BC1**	BC21	BC22	**BC2**	BC31	BC32	**BC3**	BC41	BC42	**BC4**	BC51	BC52	**BC5**	BC61	BC62	**BC6**	BC71	BC72	**BC7**
2839	2952	**2843**	2522	2626	**2524**	2476	2782	**2478**	2340	2796	**2342**	2334	2955	**2335**	2152	2559	**2153**	2230	2794	**2230**
2772	2911	**2779**	2580	2809	**2584**	2509	2855	**2513**	2343	2791	**2346**	2339	2946	**2342**	2172	2658	**2173**	2310	3014	**2312**
3601	3340	**3615**	3239	3177	**3248**	3070	2989	**3078**	2851	2806	**2857**	2778	2873	**2784**	2596	2322	**2598**	2658	2610	**2661**
2973	2487	**2988**	2748	2417	**2759**	2598	2279	**2606**	2413	2119	**2420**	2368	2181	**2374**	2171	1608	**2174**	2217	1675	**2220**
3015	3279	**3035**	2747	3094	**2760**	2625	3074	**2636**	2486	3011	**2495**	2436	3146	**2444**	2322	2912	**2326**	2385	3056	**2390**
2335	1480	**2353**	2163	1572	**2175**	2041	1384	**2051**	1891	1218	**1899**	1849	1219	**1856**	1631	490	**1634**	1681	658	**1685**
2356	2032	**2376**	2235	2092	**2249**	2123	2017	**2135**	1983	1833	**1992**	1945	1918	**1953**	1819	1427	**1823**	1885	1698	**1889**
2704	3417	**2731**	2485	3148	**2503**	2437	3256	**2453**	2313	3227	**2325**	2319	3491	**2330**	2220	3459	**2225**	2309	3658	**2315**
1966	869	**1987**	1893	1014	**1908**	1770	796	**1783**	1643	680	**1653**	1578	608	**1586**	1402	-166	**1405**	1437	-47	**1441**
2491	2726	**2520**	2318	2604	**2338**	2251	2596	**2269**	2100	2341	**2114**	2095	2544	**2108**	1964	2247	**1969**	2028	2400	**2034**
2241	1919	**2269**	2132	1879	**2153**	2041	1792	**2058**	1908	1733	**1921**	1891	1791	**1903**	1731	1280	**1736**	1800	1472	**1806**
1325	1458	**1836**	1328	1412	**1761**	1308	1398	**1681**	1300	1344	**1628**	1273	1255	**1546**	1279	1220	**1473**	1272	1193	**1460**
1524	1693	**2115**	1576	1679	**2092**	1527	1521	**1963**	1449	1408	**1815**	1464	1478	**1779**	1462	1461	**1685**	1488	1450	**1709**
1562	1749	**2170**	1584	1665	**2105**	1532	1566	**1971**	1507	1533	**1889**	1458	1391	**1772**	1516	1419	**1747**	1498	1347	**1721**
2142	2300	**2980**	2057	2144	**2736**	2040	2111	**2627**	1952	2018	**2450**	1892	1875	**2301**	1914	1810	**2208**	1925	1859	**2213**
2545	2848	**3548**	2436	2544	**3243**	2353	2357	**3033**	2279	2213	**2863**	2241	2199	**2729**	2234	2119	**2578**	2213	2132	**2546**
2283	2500	**3187**	2213	2306	**2951**	2157	2194	**2783**	2069	2040	**2601**	2006	1931	**2443**	2001	1848	**2311**	2027	1904	**2333**
2436	2983	**3409**	2303	2577	**3076**	2230	2501	**2882**	2152	2438	**2711**	2141	2384	**2612**	2115	2350	**2445**	2149	2408	**2477**

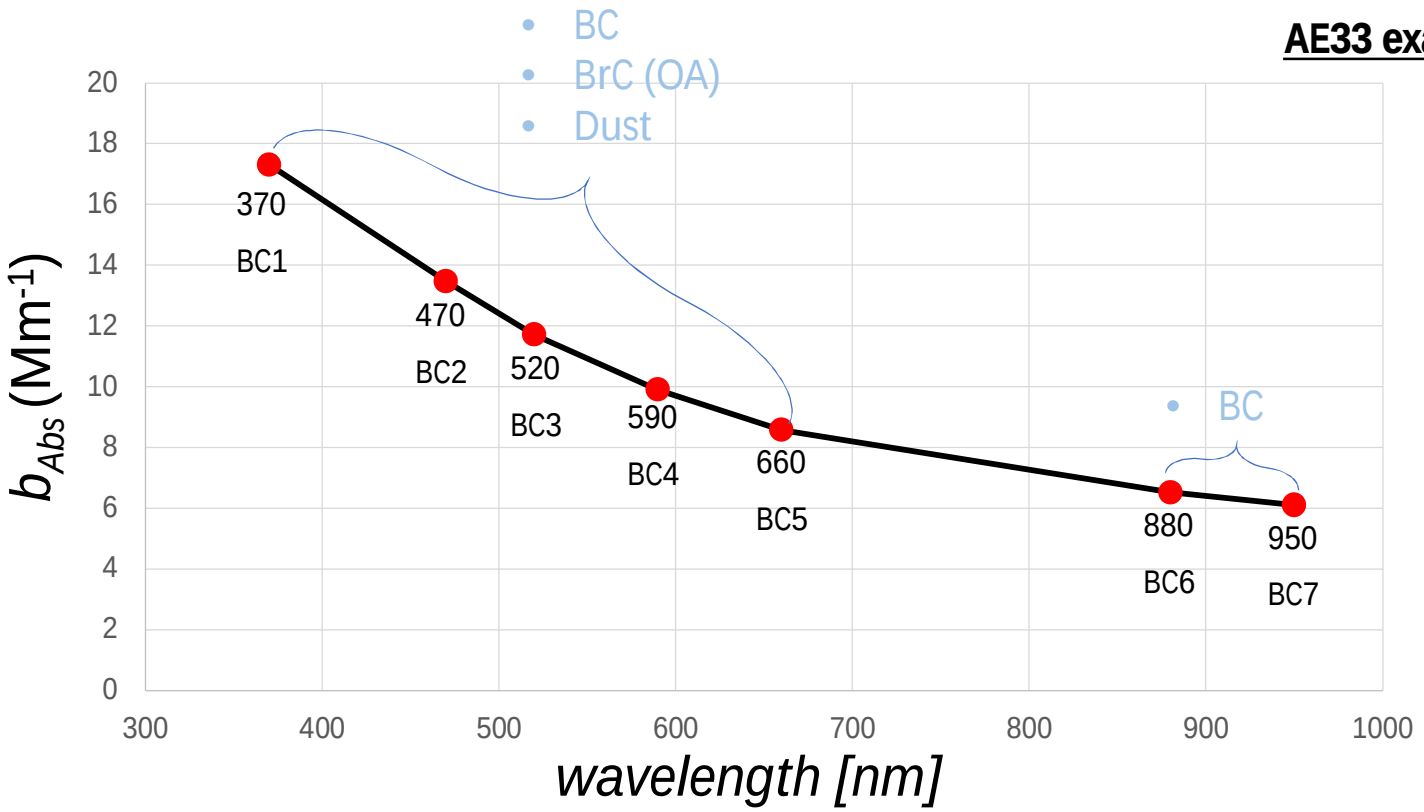
Drinovec et al., AMT, 2015

DETERMINATION OF EQUIVALENT BLACK CARBON (eBC) MASS CONCENTRATION

Aethalometers

$$eBC\ (\lambda) = \frac{b_{Abs}(\lambda)}{MAC_{BC}(\lambda)}$$

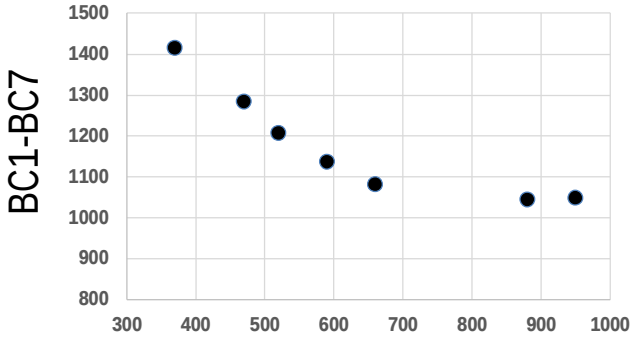
AE33 example file



DETERMINATION OF EQUIVALENT BLACK CARBON (eBC) MASS CONCENTRATION

Aethalometers

$$eBC6\ (880) = \frac{b_{Abs}(880)}{MAC_{BC}(880)}$$



AE33 example file

AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG
		ng/m3			ng/m3			ng/m3			ng/m3			ng/m3			ng/m3			ng/m3
1104	1228	**1415**	1042	1131	**1285**	1009	1076	**1208**	972	1023	**1138**	951	985	**1082**	963	96	**1045**	967	972	**1049**
	MAC,BC	**18.47**			**15.54**			**13.14**			**11.58**			**10.35**			**7.77**			**7.19**
	wavelength	**370 nm**			**470 nm**			**520 nm**			**590 nm**			**660 nm**			**880 nm**			**950 nm**
SPOT 1	SPOT 2		SPOT 1	SPOT 2		SPOT 1	SPOT 2		SPOT 1	SPOT 2		SPOT 1	SPOT 2		SPOT 1	SPOT 2		POT 1	SPOT 2	
BC11	BC12	**BC1**	BC21	BC22	**BC2**	BC31	BC32	**BC3**	BC41	BC42	**BC4**	BC51	BC52	**BC5**	BC61	BC62	**BC6**	C71	BC72	**BC7**
2839	2952	**2843**	2522	2626	**2524**	2476	2782	**2478**	2340	2796	**2342**	2334	2955	**2335**	2152	25	**2153**	2230	2794	**2230**
2772	2911	**2779**	2580	2809	**2584**	2509	2855	**2513**	2343	2791	**2346**	2339	2946	**2342**	2172	26	**2173**	2310	3014	**2312**
3601	3340	**3615**	3239	3177	**3248**	3070	2989	**3078**	2851	2806	**2857**	2778	2873	**2784**	2596	23	**2598**	2658	2610	**2661**
2973	2487	**2988**	2748	2417	**2759**	2598	2279	**2606**	2413	2119	**2420**	2368	2181	**2374**	2171	16	**2174**	2217	1675	**2220**
3015	3279	**3035**	2747	3094	**2760**	2625	3074	**2636**	2486	3011	**2495**	2436	3146	**2444**	2322	29	**2326**	2385	3056	**2390**
2335	1480	**2353**	2163	1572	**2175**	2041	1384	**2051**	1891	1218	**1899**	1849	1219	**1856**	1631	4	**1634**	1681	658	**1685**
2356	2032	**2376**	2235	2092	**2249**	2123	2017	**2135**	1983	1833	**1992**	1945	1918	**1953**	1819	14	**1823**	1885	1698	**1889**
2704	3417	**2731**	2485	3148	**2503**	2437	3256	**2453**	2313	3227	**2325**	2319	3491	**2330**	2220	34	**2225**	2309	3658	**2315**
1966	869	**1987**	1893	1014	**1908**	1770	796	**1783**	1643	680	**1653**	1578	608	**1586**	1402	-1	**1405**	1437	-47	**1441**
2491	2726	**2520**	2318	2604	**2338**	2251	2596	**2269**	2100	2341	**2114**	2095	2544	**2108**	1964	22	**1969**	2028	2400	**2034**
2241	1919	**2269**	2132	1879	**2153**	2041	1792	**2058**	1908	1733	**1921**	1891	1791	**1903**	1731	12	**1736**	1800	1472	**1806**
1325	1458	**1836**	1328	1412	**1761**	1308	1398	**1681**	1300	1344	**1628**	1273	1255	**1546**	1279	12	**1473**	1272	1193	**1460**
1524	1693	**2115**	1576	1679	**2092**	1527	1521	**1963**	1449	1408	**1815**	1464	1478	**1779**	1462	14	**1685**	1488	1450	**1709**
1562	1749	**2170**	1584	1665	**2105**	1532	1566	**1971**	1507	1533	**1889**	1458	1391	**1772**	1516	14	**1747**	1498	1347	**1721**
2142	2300	**2980**	2057	2144	**2736**	2040	2111	**2627**	1952	2018	**2450**	1892	1875	**2301**	1914	18	**2208**	1925	1859	**2213**
2545	2848	**3548**	2436	2544	**3243**	2353	2357	**3033**	2279	2213	**2863**	2241	2199	**2729**	2234	21	**2578**	2213	2132	**2546**
2283	2500	**3187**	2213	2306	**2951**	2157	2194	**2783**	2069	2040	**2601**	2006	1931	**2443**	2001	18	**2311**	2027	1904	**2333**
2436	2983	**3409**	2303	2577	**3076**	2230	2501	**2882**	2152	2438	**2711**	2141	2384	**2612**	2115	23	**2445**	2149	2408	**2477**

Drinovec et al., AMT, 2015

DETERMINATION OF EQUIVALENT BLACK CARBON (eBC) MASS CONCENTRATION

Aethalometers

$$eBC6\ (880) = \frac{b_{Abs}(880)}{MAC_{BC}(880)} \rightarrow b_{ABS}(880) = \frac{b_{ATN}(880)}{1.39} \rightarrow 7.77\ m^2/g$$

AE33 example file

AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG
		ng/m3			ng/m3			ng/m3			ng/m3			ng/m3			ng/m3			ng/m3
1104	1228	**1415**	1042	1131	**1285**	1009	1076	**1208**	972	1023	**1138**	951	985	**1082**	963	96	**1045**	967	972	**1049**
	MAC,BC	**18.47**			**15.54**			**13.14**			**11.58**			**10.35**			**7.77**			**7.19**
	wavelength	**370 nm**			**470 nm**			**520 nm**			**590 nm**			**660 nm**			**880 nm**			**950 nm**
SPOT 1	SPOT 2		SPOT 1	SPOT 2		SPOT 1	SPOT 2		SPOT 1	SPOT 2		SPOT 1	SPOT 2		SPOT 1	SPOT 2		POT 1	SPOT 2	
BC11	BC12	**BC1**	BC21	BC22	**BC2**	BC31	BC32	**BC3**	BC41	BC42	**BC4**	BC51	BC52	**BC5**	BC61	BC62	**BC6**	C71	BC72	**BC7**
2839	2952	**2843**	2522	2626	**2524**	2476	2782	**2478**	2340	2796	**2342**	2334	2955	**2335**	2152	25	**2153**	2230	2794	**2230**
2772	2911	**2779**	2580	2809	**2584**	2509	2855	**2513**	2343	2791	**2346**	2339	2946	**2342**	2172	26	**2173**	2310	3014	**2312**
3601	3340	**3615**	3239	3177	**3248**	3070	2989	**3078**	2851	2806	**2857**	2778	2873	**2784**	2596	23	**2598**	2658	2610	**2661**
2973	2487	**2988**	2748	2417	**2759**	2598	2279	**2606**	2413	2119	**2420**	2368	2181	**2374**	2171	16	**2174**	2217	1675	**2220**
3015	3279	**3035**	2747	3094	**2760**	2625	3074	**2636**	2486	3011	**2495**	2436	3146	**2444**	2322	29	**2326**	2385	3056	**2390**
2335	1480	**2353**	2163	1572	**2175**	2041	1384	**2051**	1891	1218	**1899**	1849	1219	**1856**	1631	4	**1634**	1681	658	**1685**
2356	2032	**2376**	2235	2092	**2249**	2123	2017	**2135**	1983	1833	**1992**	1945	1918	**1953**	1819	14	**1823**	1885	1698	**1889**
2704	3417	**2731**	2485	3148	**2503**	2437	3256	**2453**	2313	3227	**2325**	2319	3491	**2330**	2220	34	**2225**	2309	3658	**2315**
1966	869	**1987**	1893	1014	**1908**	1770	796	**1783**	1643	680	**1653**	1578	608	**1586**	1402	-1	**1405**	1437	-47	**1441**
2491	2726	**2520**	2318	2604	**2338**	2251	2596	**2269**	2100	2341	**2114**	2095	2544	**2108**	1964	22	**1969**	2028	2400	**2034**
2241	1919	**2269**	2132	1879	**2153**	2041	1792	**2058**	1908	1733	**1921**	1891	1791	**1903**	1731	12	**1736**	1800	1472	**1806**
1325	1458	**1836**	1328	1412	**1761**	1308	1398	**1681**	1300	1344	**1628**	1273	1255	**1546**	1279	12	**1473**	1272	1193	**1460**
1524	1693	**2115**	1576	1679	**2092**	1527	1521	**1963**	1449	1408	**1815**	1464	1478	**1779**	1462	14	**1685**	1488	1450	**1709**
1562	1749	**2170**	1584	1665	**2105**	1532	1566	**1971**	1507	1533	**1889**	1458	1391	**1772**	1516	14	**1747**	1498	1347	**1721**
2142	2300	**2980**	2057	2144	**2736**	2040	2111	**2627**	1952	2018	**2450**	1892	1875	**2301**	1914	18	**2208**	1925	1859	**2213**
2545	2848	**3548**	2436	2544	**3243**	2353	2357	**3033**	2279	2213	**2863**	2241	2199	**2729**	2234	21	**2578**	2213	2132	**2546**
2283	2500	**3187**	2213	2306	**2951**	2157	2194	**2783**	2069	2040	**2601**	2006	1931	**2443**	2001	18	**2311**	2027	1904	**2333**
2436	2983	**3409**	2303	2577	**3076**	2230	2501	**2882**	2152	2438	**2711**	2141	2384	**2612**	2115	23	**2445**	2149	2408	**2477**

Drinovec et al., AMT, 2015

STEPS TO GO FURTHER WHAT FAPs ARE PROVIDING AS RAW DATA (eBC)

Aethalometers

$$eBC6\ (880) = \frac{b_{Abs}(880)}{MAC_{BC}(880)}$$

$$b_{ABS}(880) = \frac{b_{ATN}(880)}{1.39}$$

$7.77\ m^2/g$

ACTRIS/RI-URBANS HARMONIZATION of C and MAC

STEPS TO GO FURTHER WHAT FAPs ARE PROVIDING AS RAW DATA (eBC)

Aethalometers

$$eBC6\ (880) = \frac{b_{Abs}(880)}{MAC_{BC}(880)} \rightarrow 7.77\ m^2/g \rightarrow b_{ABS}(880) = \frac{b_{ATN}(880)}{1.39}$$

$$C^* = \frac{b_{ATN}}{b_{Abs}^{MAAP}} = 2.44$$

$$H^* = \frac{C^*}{C} = \frac{2.44}{1.39} = 1.76$$

$$b_{ABS}^* = \frac{b_{ABS}}{H^*}$$

$$b_{ABS}^*(880) = \frac{BC6 \times 7.77}{1.76}$$

$$eBC^* = \frac{BC6}{1.76}$$

European Center for Aerosol Calibration and Characterization (**CAIS-ECAC**)
European Research Infrastructure **ACTRIS-ERIC**

T. Müller, M. Fiebig, 2018
ACTRIS In Situ Aerosol: Guidelines for Manual QC of AE33 Absorption Photometer Data
https://www.actris-ecac.eu/

STEPS TO GO FURTHER WHAT FAPs ARE PROVIDING AS RAW DATA (eBC)

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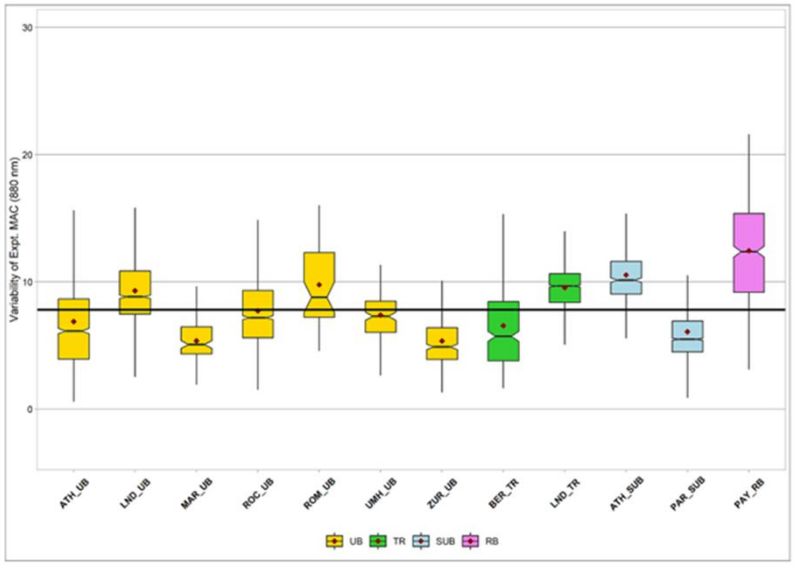
7.77 m²/g

$$b^{*}_{ABS}(880) = \frac{BC6 \times 7.77}{1.76}$$ (LEVEL2 EBAS)

$$eBC^{*} = \frac{BC6}{1.76}$$ (LEVEL3 EBAS)

$$eBC^{*,L} = \frac{b^{*}_{Abs}(880)}{MAC^{L}_{BC}(880)}$$

$$MAC^{L}_{BC}(880) = \frac{b^{*}_{Abs}(880)}{EC}$$



RI-URBANS (Savadkoohi et al. 2024)

STEPS TO GO FURTHER WHAT FAPs ARE PROVIDING AS RAW DATA (eBC)

Aethalometers

$$eBC6\ (880) = \frac{b_{Abs}(880)}{MAC_{BC}(880)}$$

$b_{Abs}(880)$ → $b_{ABS}(880) = \frac{b_{ATN}(880)}{1.39}$

$MAC_{BC}(880)$ → 7.77 m²/g

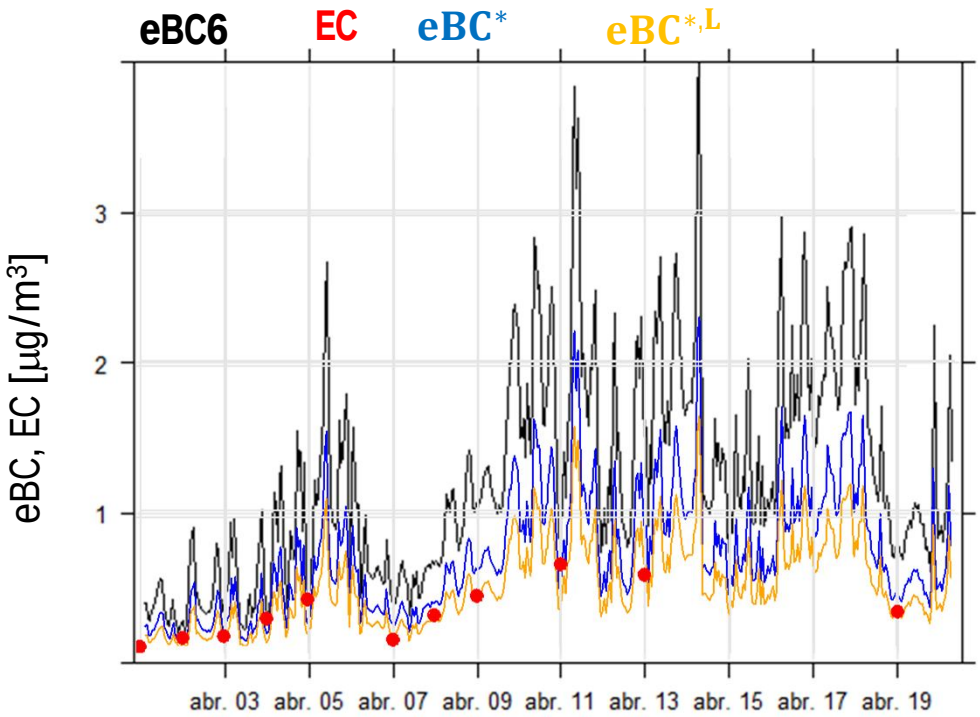
$$b^{*}_{ABS}(880) = \frac{BC6 \times 7.77}{1.76}$$ (LEVEL2 EBAS)

$$eBC^{*} = \frac{BC6}{1.76}$$ (LEVEL3 EBAS)

$$eBC^{*,L} = \frac{b^{*}_{Abs}(880)}{MAC^{L}_{BC}(880)}$$

$$MAC^{L}_{BC}(880) = \frac{b^{*}_{Abs}(880)}{EC}$$

MAC^{L}=10.8 m²/g



STEPS TO GO FURTHER WHAT FAPs ARE PROVIDING AS RAW DATA (eBC)

Aethalometers

$$b^*_{ABS}(880) = \frac{BC6 \times 7.77}{1.76}$$ (LEVEL2 EBAS)

$$eBC^* = \frac{BC6}{1.76}$$ (LEVEL3 EBAS)

$$eBC^{*,L} = \frac{b^*_{Abs}(880)}{MAC^L_{BC}(880)}$$

$$MAC^L_{BC}(880) = \frac{b^*_{Abs}(880)}{EC}$$

- **eBC^* should be reported from AQMN measurement sites**
- If EC is available (UB/RB supersite) the local MAC_L can be calculated to report $eBC^{*,L}$
- $eBC^{*,L}$ can be calculated using an average MAC_L value or time-dependent MAC_L

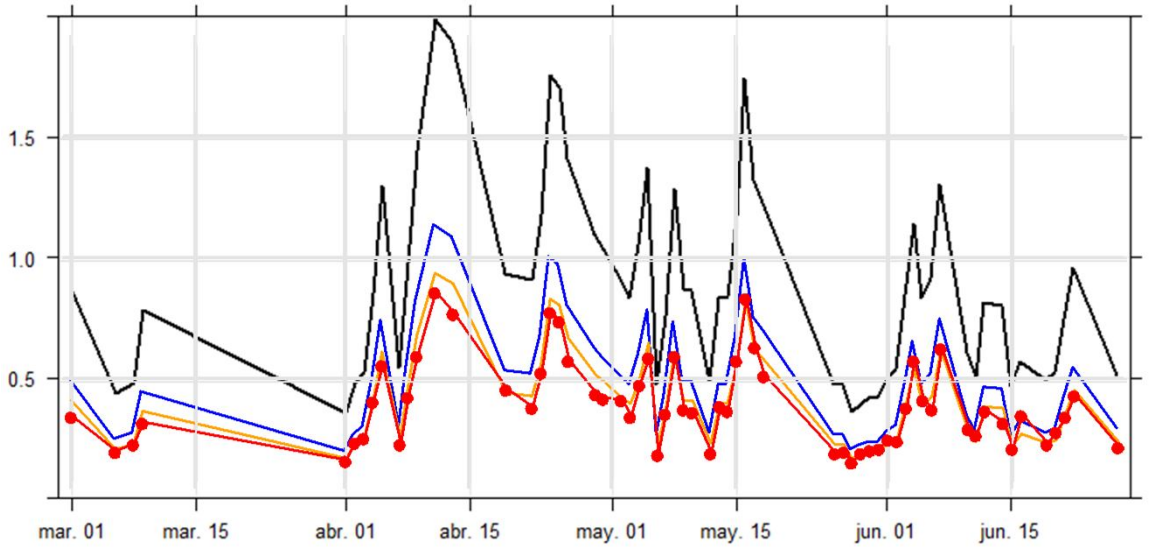
eBC6

eBC^*

< MACL > $eBC^{*,L}$

MAC_L (t) $eBC^{*,L}$

EC



STEPS TO GO FURTHER WHAT FAPs ARE PROVIDING AS RAW DATA (eBC)

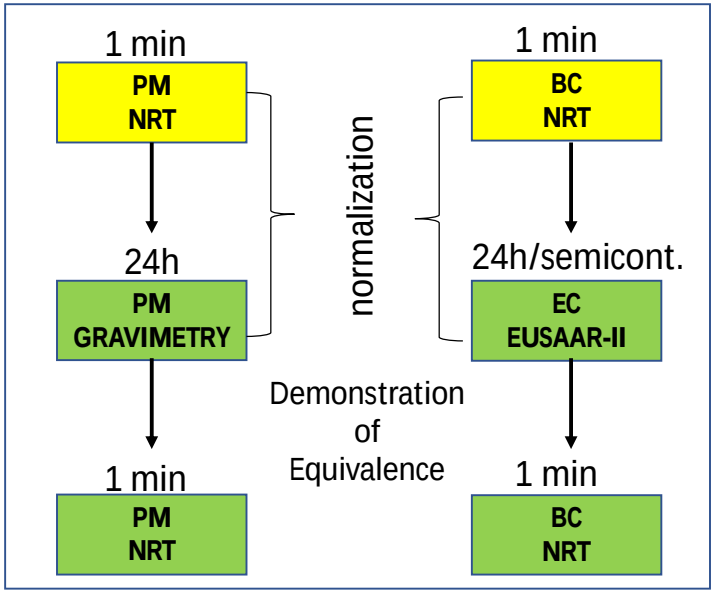
- For demonstrating the equivalence of a candidate method (e.g. the Beta-gauge technique) with the reference (gravimetric) method, it is allowed to establish first a site and time dependent calibration factor.
- Using site and time dependent MAC values would very probably make it possible to demonstrate the equivalence between FAP techniques and the CEN standard method (EN16909) for determining EC.

The EN 16909 standard method for determining EC → EC

GRAVIMETRY Protocol for Europe (Reference technique) → PM

BC ← FAPs (filter absorption photometers; MAAP, AE33, AE36)

PM ← NRT techniques for PM mass concentration (GRIMM;...)

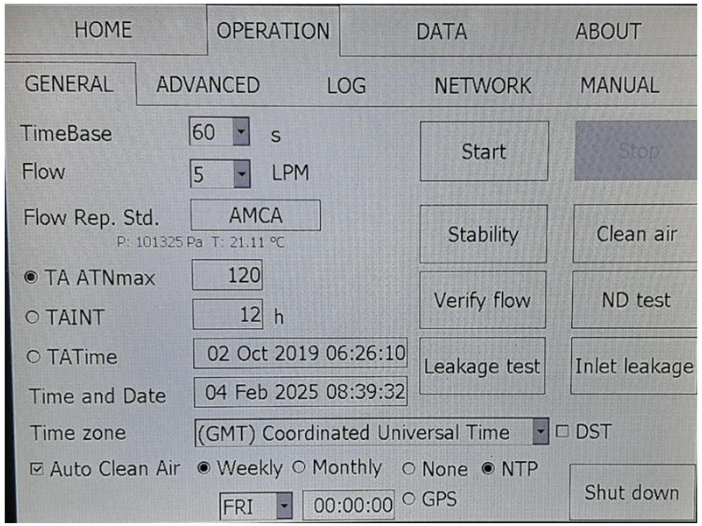


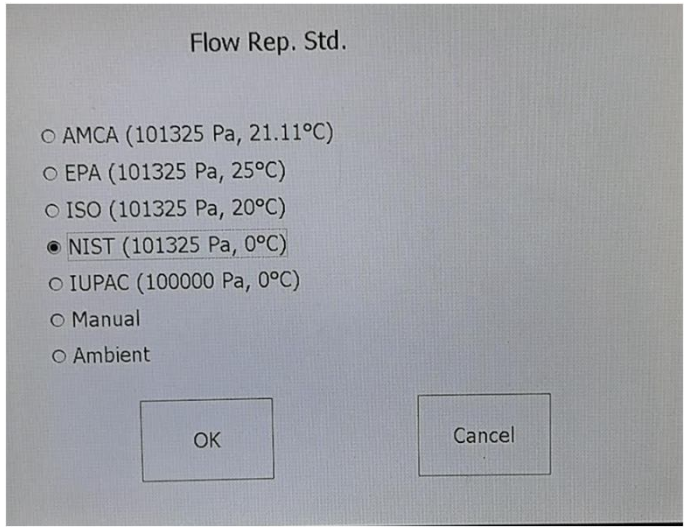
Aethalometers operation and maintenance

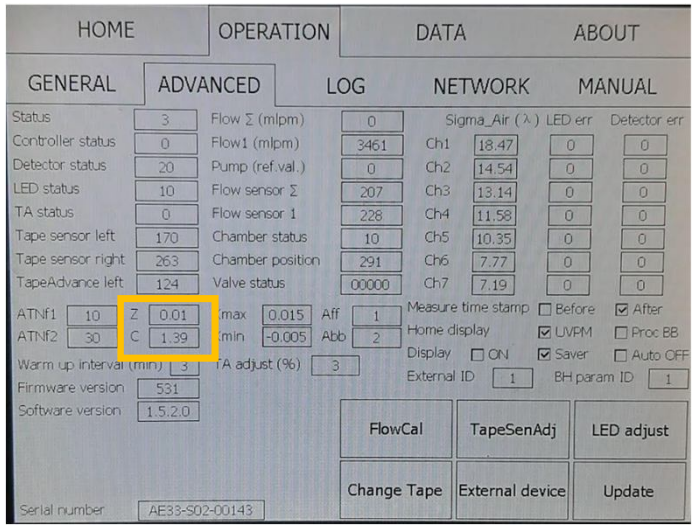
GENERAL

- Aethalometers are stable instruments and do not require frequent maintenance
- The most frequent routine maintenances are the filter change, check the inlet flow or inspect the sample line tubing
- It does not require a specialized technician or researcher. A little training is sufficient
- It is important to check, for example weekly, the screen to see if error messages have appeared
- The graphical interface of the Aethalometers allows to know if any maintenance is needed and what type of maintenance
- Aethalometer manuals are provided by the manufacturer
- https://www.youtube.com/watch?v=ZoUzaqMi2EQ (Aethalometers operation and maintenance)
- A number of technical guidance documents and reports about Aethalometers (and other FAPs) are available from Global Atmosphere Watch (GAW; https://www.gaw-wdca.org/Publications/) and ACTRIS (https://www.actris-ecac.eu/particle-light-absorption.html) that provide comprehensive recommendations and guidelines including operating procedures, aerosol inlets and conditioning, data management among other. The service tools from RI-URBANS project (https://riurbans.eu/project/#service-tools) to assess air quality in accordance with RI-URBANS' advanced air quality monitoring recommendations and with the ACTRIS/GAW protocols for measuring advanced air quality parameters

MAIN SETTINGS







- 60 s time resolution
- 5 LPM
- Flow Rep. Std.
- ATN max 370 nm (120)
- Weekly Auto Clean Air Test
- Z=0.01 (tangential leakage through the edges of the filter tape)
- C=1.39 (optical enhancement factor; M8060)

OPERATION AND MAINTENANCE

13.1 Startup screen checks

OPERATION AND MAINTENANCE

Check	Description	Error	Solution
Communication	communication PC to optical chamber controller	hardware problem	check cables
Instrument data	Obtain data (serial number) from the optical chamber controller	hardware problem	check cables
Storage	CF card operation	CF card error	get new CF card and SW
Configuration settings	read setting from the setup file	Setup file error	restore setup file from one of the older setup files
Valves	operation of the ball valve	ball valve not moving	check cables
Chamber	optical chamber movement test	locked chamber	unlock chamber
		hardware error	service needed
Pump & Flow	test if pump is working	pump	service needed
		tube connections	reconnect tubes
Device monitoring	Win CE operating system test	faulty application file	get new CF card and SW

OPERATION AND MAINTENANCE

https://www.actris-ecac.eu/particle-light-absorption.html

- Check the instrument status. Status messages other than normal operation (0 = no error and no warning) should be checked and data flagged accordingly
- Sample pressure and temperature: AE33 does not measure ambient temperature and pressure without connecting to an external sensor.
- Sample relative humidity at inlet (sensors not built in to AE33) Sample relative humidity varies with ambient relative humidity and the temperature difference between ambient and lab. The sample should be dried so that the sample has RH < 40% already at the instrument inlet. If RH is higher, apply flag 640. Since the AE33 does not measure RH, it is valid to measure the humidity at the inlet of another device that is located at the same common aerosol inlet and under similar conditions.
- Sample flow: Sample flow through the instrument inlet should be constant. The sample flow should typically be 5 l/min and shall not vary. Flow variations directly affect the signal to noise ratio. Spikes in the flow inevitably lead to outliers in equivalent black carbon concentrations. Periods showing problems with the flow must be flagged.
- Filter type : It is mandatory to report the filter tape and respective multiple scattering correction factors (C) in level 0 header data which have actually been used while collecting the data. Also make sure to verify the correct multiple scattering correction factor in the instrument settings. The recommended filter type is M8060 with a multi-scattering correction factor 1.39. For other filter types, please check the appendix. Add scattering correction factor and leakage factor to the Nasa-ames header.

OPERATION AND MAINTENANCE

t-absorption.html

- Check the instrument status. Statu
  flagged accordingly
- Sample pressure and temperature:
- Sample relative humidity at inlet (s
  temperature difference between a
  inlet. If RH is higher, apply flag 640
  that is located at the same commo
- Sample flow: Sample flow through
  Flow variations directly affect the s
  concentrations. Periods showing p
- Filter type : It is mandatory to repo
  have actually been used while colle
  instrument settings. The recomme
  check the appendix. Add scattering

Status relates to:	bit position	status flag		description
		binary	decimal	
Operation	1 and 0	00	0	Measurement
		01	1	Tape advance (tape advance, fast calibration, warm-up)
		10	2	First measurement – obtaining ATN0
		11	3	Stopped
Flow	3 and 2	00		Flow OK
		01	4	Flow low/high by more than 0.5 LPM or F1 < 0 or F2/F1 outside 0.2 – 0.75 range
		10	8	Check flow status history
		11	12	Flow low/high & check flow status history
Optical Source	5 and 4	00		LEDs OK
		01	16	Calibrating LED
		10	32	Calibration error (at least one channel OK)
		11	48	LED error (all channels calibration error, COM error)

checked and data

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OPERATION AND MAINTENANCE

https://www.actris-ecac.eu/particle-light-absorption.html

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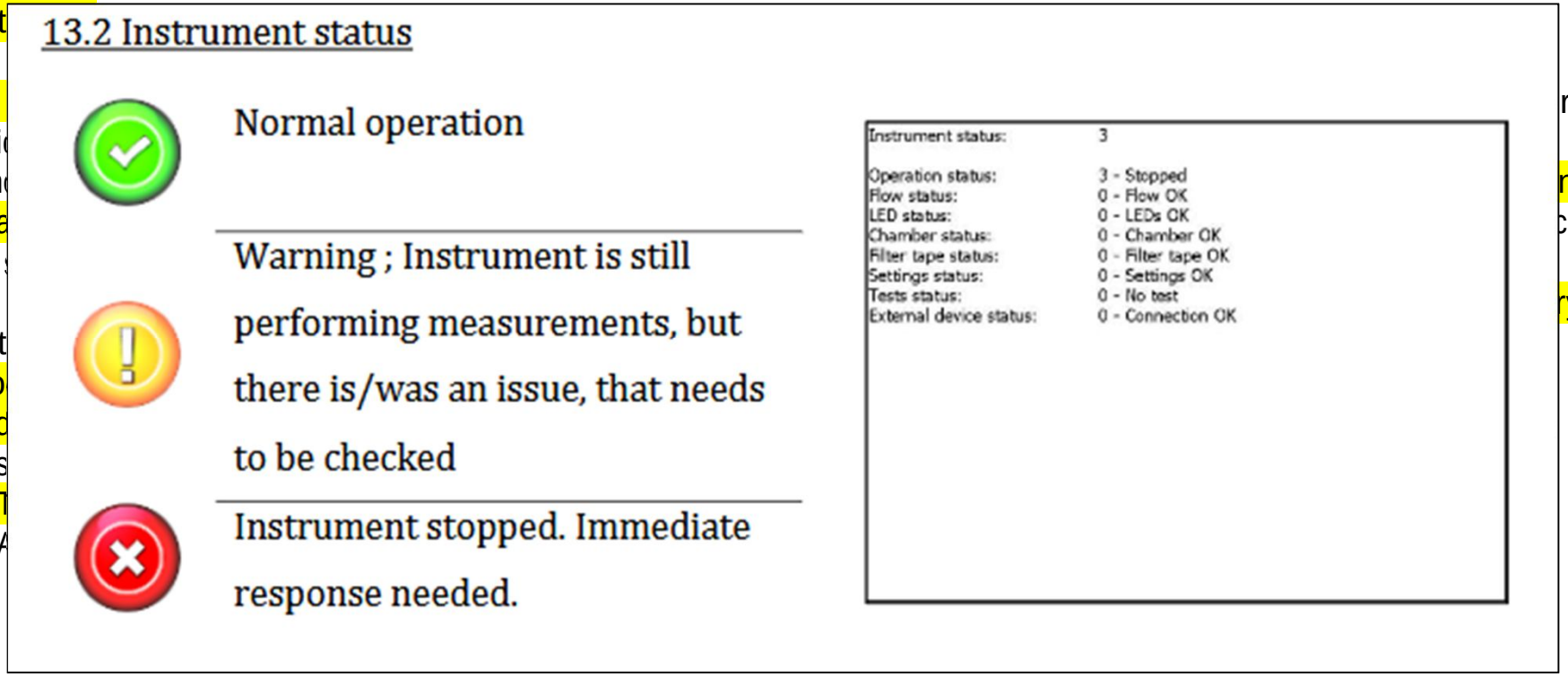

OPERATION AND MAINTENANCE

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OPERATION AND MAINTENANCE

Check the sample inlet flow	Once / month
Inspect the sample line tubing	Once / month
Inspect and clean the size selective inlet (if present)	Once / month
Inspect and clean the insect screen assembly (if present)	Once / month
Verify time and date (if not set to update automatically)	Once / month
Inspect optical chamber, clean if necessary	Once / 6 months* *Site dependent, use educated judgment!
Flow check (flow verification, flow calibration)	Once / 6 months
Clean Air Test	Once / 6 months
Stability Test	Once / 6 months
ND filter test	Once / year
Lubricate optical chamber sliders	Once / year
Install a new filter tape roll	As needed. The instrument issues a warning.
Change by-pass cartridge filter	As needed. Once / year

Standard maintenance procedures are shown in video clips at http://group.mageesci.com/

OPERATION AND MAINTENANCE

https://www.actris-ecac.eu/aerosol-inlets-and-conditioning.html

- Drying technology: four possibilities drying the aerosol sample flow to a RH below 40%.

- Membrane dryers (Nafion): permeable membrane in which water vapor molecules are transported
- Diffusion dryers: water vapor is adsorbed by the silica gel
- Drying by dilution: This method requires the continuous provision of particle-free dry air
- Drying by heating: heating an aerosol sample leads to a reduction of RH in the sampling line

- PM10 or PM2.5 inlet

- Observational networks, such as WMO-GAW, recommend an upper cut point of 10 µm at ambient conditions (WMO-GAW report 153)
- If EC measurements are available in PM2.5, a PM2.5 inlet for AE33 can be used.
- To measure aerosol particles the air inlet must be generally between 1.5 m and 4 m above the ground (2008/50/EC). Sampling tubes should be made of a conductive, corrosion-resistant material with a low surface roughness (e.g., stainless steel).
- Aethalometers can be connected to a single dedicated inlet or to common inlet through an isokinetic splitter.

RI-URBANS SERVICE TOOLS: eBC

https://riurbans.eu/project/#service-tools

Explore all our advanced Service Tools for optimised urban air quality management:

− Protocols for the measurement of novel AQ pollutants

ST1:Ultrafine (=nano)-Particle Number Size Distributions (UFP-PNSD)

ST2: Black Carbon (BC)

ST3: Offline and Online particulate matter (PM) speciation

ST4:Oxidative potential (OP) of particulate matter (PM)

ST5: Volatile Organic Compounds (VOCs)

ST6: Ammonia (NH3)

+ Methodologies for vertical profiles of pollutants and meteorology

+ Methodologies for source apportionment receptor modelling

+ Methodologies for urban mapping of novel AQ pollutants

+ Methodologies for evaluating the health effects of novel AQ pollutants

+ Obtaining emission inventories for novel AQ pollutants

+ Modelling methodologies for novel AQ pollutants

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CAIS ECAC

RI-URBANS SERVICE TOOLS: eBC

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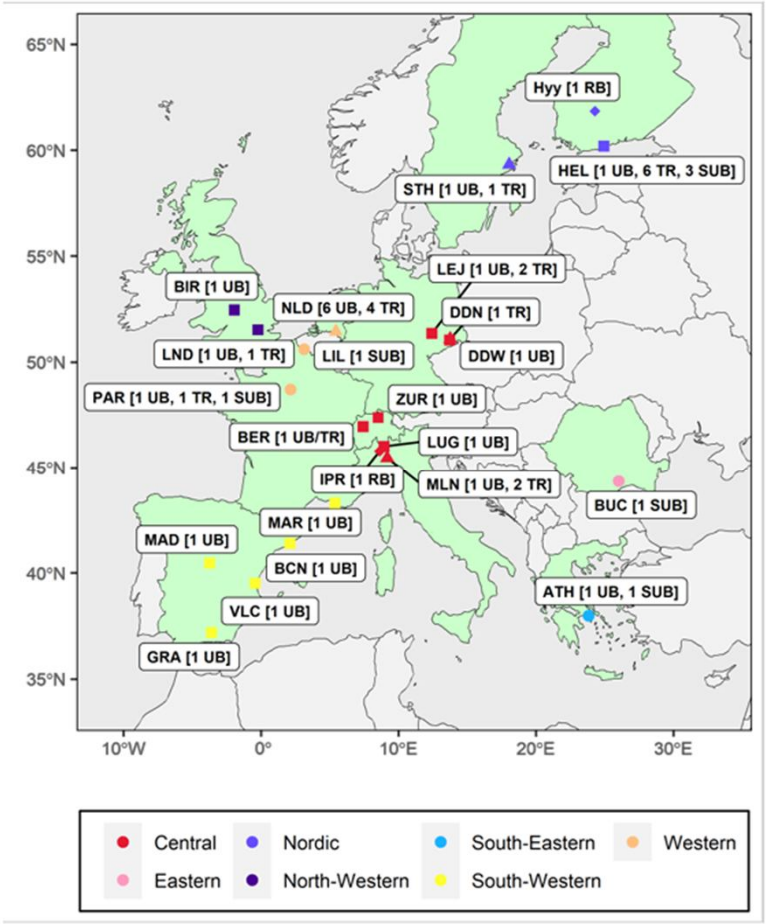
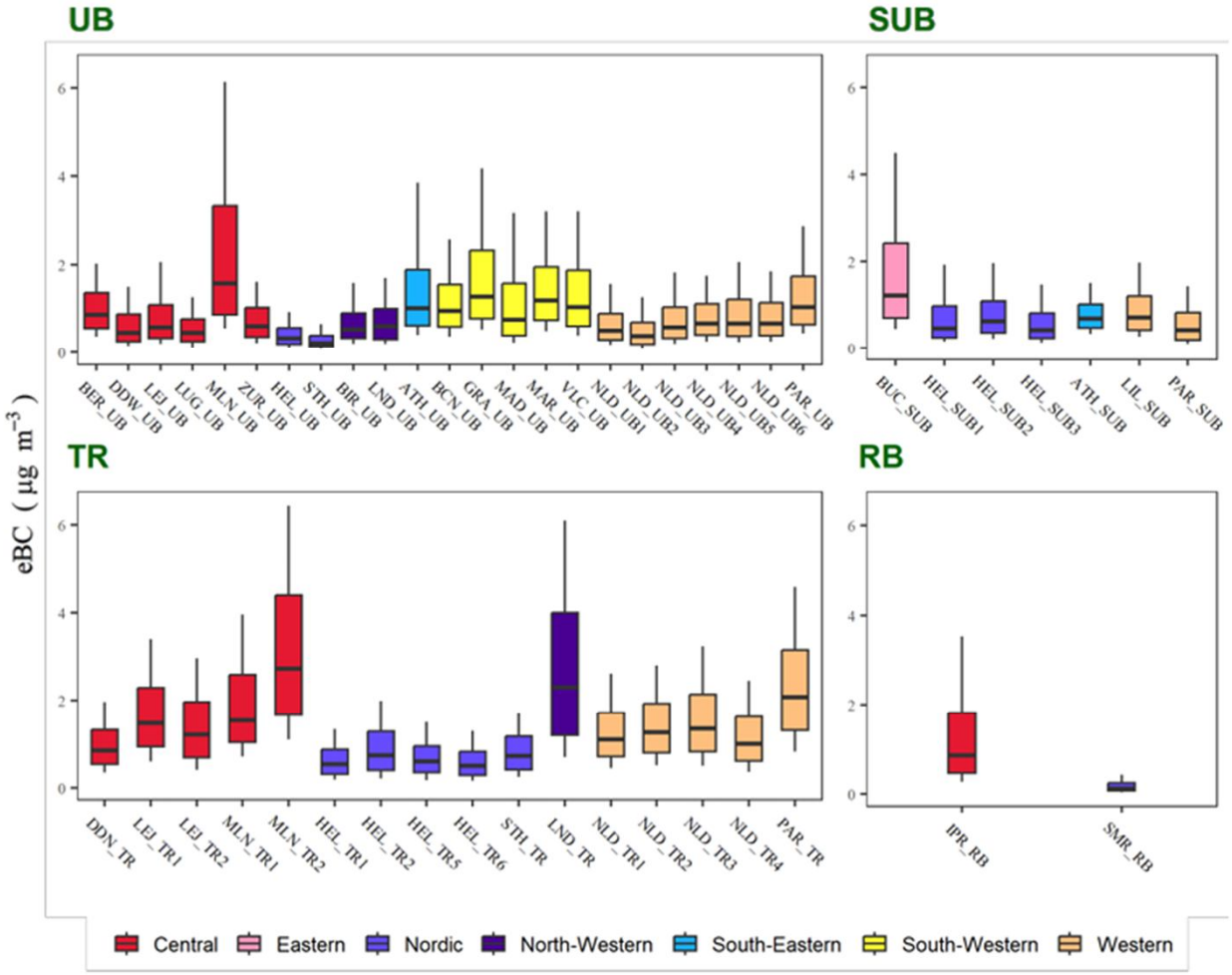


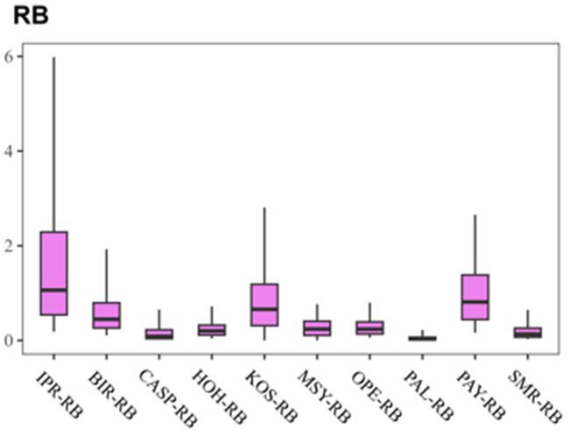
Savadkoohi et al. (2023)

Figure 1. *Distribution of the monitoring sites with eBC data. UB: urban background; SUB: suburban background; TR: traffic; RB: regional background. Modified from Savadkoohi et al. (2023).*

RI-URBANS SERVICE TOOLS: eBC

https://riurbans.eu/project/#service-tools



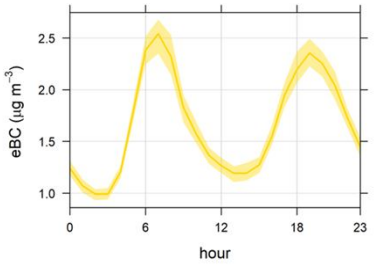


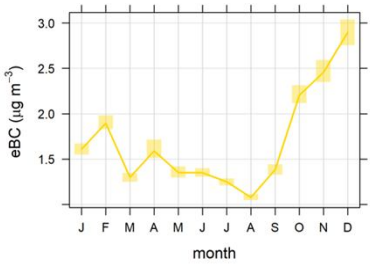
Savadkoohi et al. (2023)

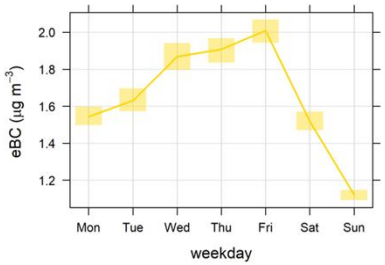
Figure 2. *Variability of hourly averaged eBC mass concentrations at 50 sites between 2017 and 2019 categorized by the type of site and region. Modified from Savadkoohi et al. (2023).*

RI-URBANS SERVICE TOOLS: eBC

BCN







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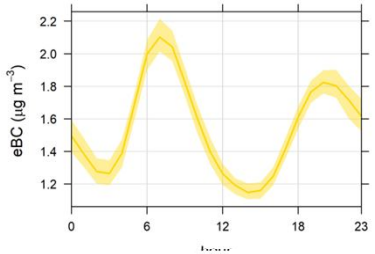

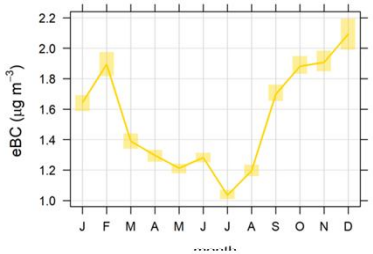

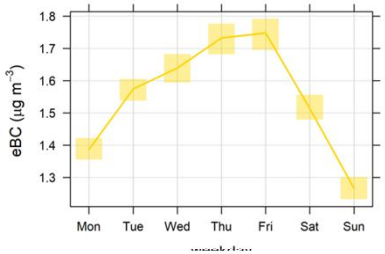

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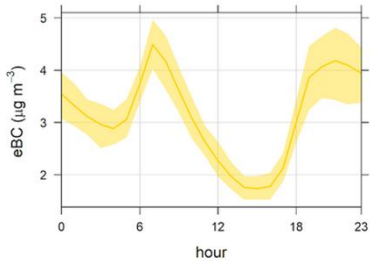

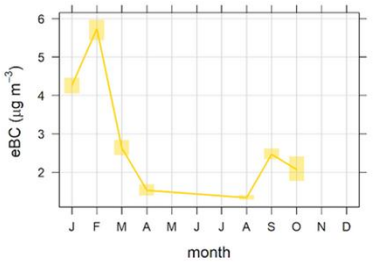

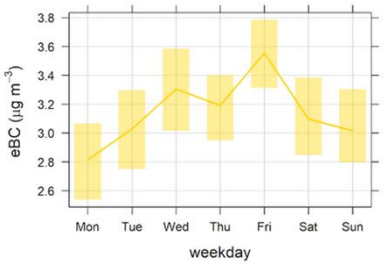

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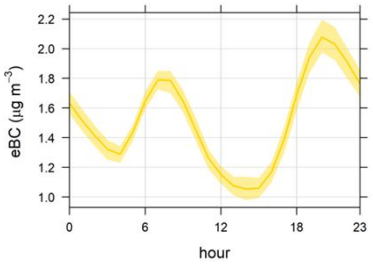
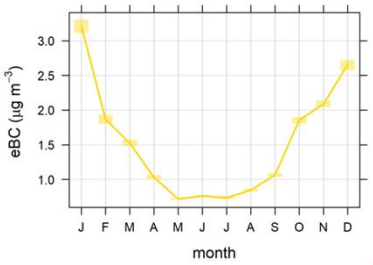
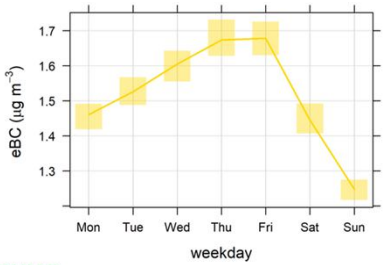
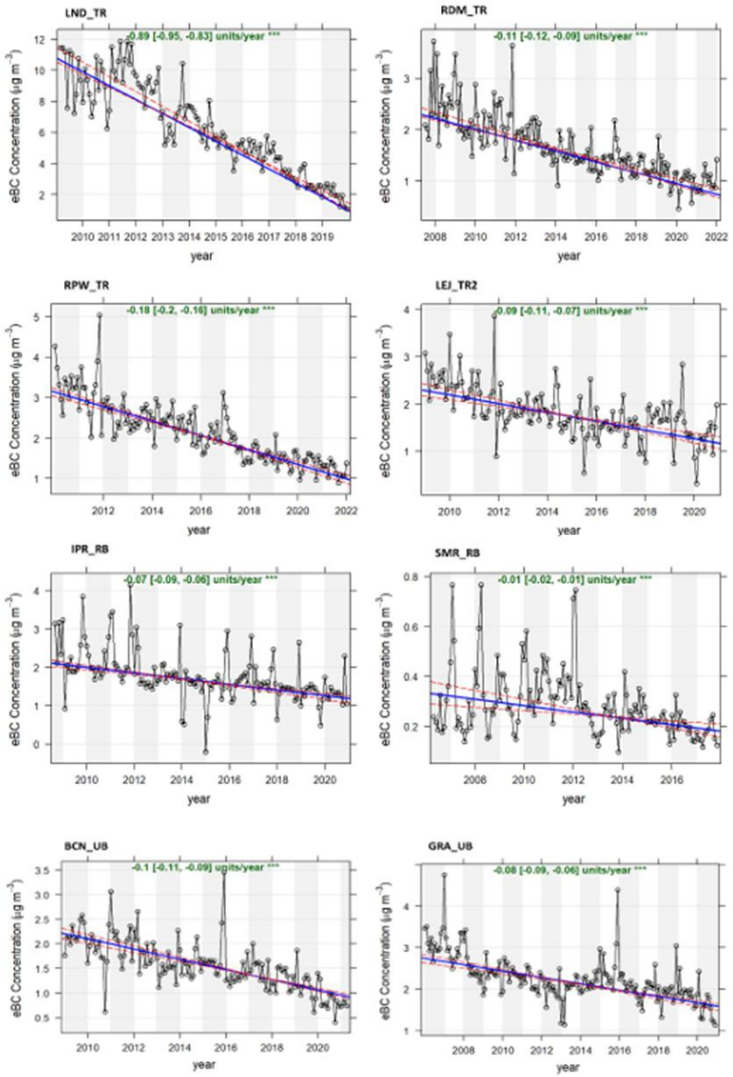






https://riurbans.eu/project/#service-tools

RI-URBANS SERVICE TOOLS: eBC



https://riurbans.eu/project/#service-tools

Savadkoohi et al. (2023)

Courtesy of Aerosol Magee Scientific

1.Pricing for New Instruments

- The price range for a new instrument is between €27,000 and €37,000, depending on the model.
- Notably, we offer a discount on our AE33 model. Depending on the project scope, the final price for the AE33 can be significantly lower than €27,000.

2.Consumable Costs

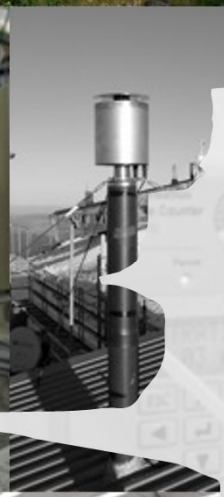
- All Aethalometers use the same consumables: filter tape and cartridge filters. These are the only two required consumables.
- On average, the annual consumption per instrument is 2-3 filter tapes and one cartridge filter, with a total cost of approximately €500 per year. The consumption of the filter tape depends on the concentrations measured by the instrument or, indirectly, on the location where it is installed.

3.Maintenance Requirements

- Standard maintenance includes flow calibration and routine checks of optical and electronic components twice a year. Importantly, these procedures can be performed by the user and do not require the involvement of certified or trained technicians. As such, there are no additional mandatory maintenance costs.

4.Optional Annual Service and Maintenance

- Aerosol offers an optional Annual Service and Maintenance package. This comprehensive service includes:
  - Full physical inspection of the unit.
  - Hardware upgrades to the latest released series.
  - Software upgrades to the latest released version.
  - Identification of potential issues.
  - Complete unit testing, including flow calibration, verification, clean air tests, ND tests, stability checks, leakage tests, long-term indoor testing, and comparison with reference instruments.
  - Data inspection and compilation of a Final Inspection Record (FIR).
- While this service is optional and not mandatory, it provides additional peace of mind. The cost for this service is approximately €2,000.

RI URBANS

European Commission

ACTRIS

CAIS-ECAC
Center for Aerosol In-Situ - European Center for Aerosol Calibration and Characterization

MANY THANKS!

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WCCAP World Calibration Centre for Aerosol Physics

OGTAC-CC

European Reference Laboratory for Air Pollution

ACMCC Aerosol Chemical Monitor Calibration Center

EMC2 Elemental Mass Calibration Centre

CCC Cluster Calibration Center