Black Carbon Concentration Trend in the South-Eastern Baltic Region

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Introduction

A comprehensive study of in-situ optical measurements at GAW and IMPROVE stations carried out by Collaud Coen et al. (2013) for the last 20-year time period revealed that the decreasing trends of scattering and/or absorbing aerosol signals prevail in the northern hemisphere. However, the increase in aerosol decadal trends of absorption coefficient by a few percent per year was also observed at several measurement stations, located on islands and classified either as mountain or as marine sites. The status of equivalent black carbon (eBC) in the South-Eastern Baltic Region starting from 2008 was analysed fragmentally in several scientific publications. This study presents the current situation of black carbon trends in the South-Eastern Baltic Sea region. The causes of the eBC long-term trend were assesed based on the analysis of possible local and regional sources and an overview of previous eBC studies for this region.

Methods

The measurements were conducted at the Preila Environmental pollution research station (55°55′ N, 21°04′ E), which is located in the south-eastern part of Baltic sea and clasified as coastal/rural background site. The aerosol absorption data was gathered with an aethalometer (model AE31, Magee Sci. Co.) for the period of 2008-2015. Empirical filter loading correction algorithm was applied to aerosol absorption data (Virkkula et al., 2007). A thorough statistical analysis of annual, seasonal and monthly eBC variations was conducted. The trend analysis was carried out using parametric: linear regression and the least square method (MLS) The time-series of the measured eBC mass concentration were analysed by decomposing them into a set of certain functions: a trend, periodic fluctuations, etc. Therefore, eBC concentration can be resolved by the sum of these components, as described in Eq. (1):

$$c(t) = A(t)\sin(f) + T(t) + \partial(t) \quad \text{Eq. (1)}$$

where $A(t)$ sin(f) is the time dependent annual amplitude with the repeating period of one year, $T(t)$ – the trend function, in general, and $\delta(t)$ – other components (e. g. noise), which were not considered in this study.
The aethalometer model (Sandradewi et al., 2008) was employed for distinguishing biomass burning and traffic sources:

$$\frac{b(470)_{abs}^{ff}}{b(950)_{abs}^{ff}} = \left(\frac{470}{950}\right)^{-\alpha_F} \quad \text{Eq.(2)} \qquad \frac{b(470)_{abs}^{bb}}{b(950)_{abs}^{bb}} = \left(\frac{470}{950}\right)^{-\alpha_B} \quad \text{Eq.(3)}$$

$$b(470)_{abs} = b(470)_{abs}^{ff} + b(470)_{abs}^{bb} \quad \text{Eq. (4)}$$

where $b(\lambda)_{abs}$ is absorption coefficient, Angstrom exponents defined as α_{FF} = 1 in case of fossil fuel and α_{BB} = 1 in case biomass burning sources. Standard values for conversion from instrument's measured attenuation coeficient $b(\lambda)_{ATN}$ to $b(\lambda)_{abs}$ were applied, i.e. mass absorption cross-section σ_{air}= 31.1 (λ = 470 nm) and 15.4 m²/g (950 nm), multiple scattering parameter - C = 1.75.

The seasonal Mann-Kendall method was applied to statistically assess the linear upward or downward trend of the variable of interest over time. For trend variability analysis, the eBC data time-series were splitted into two parts and the t-test applied.

Results

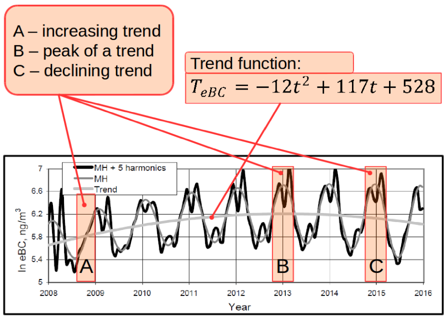

Fig. 1. The aproximation of the eBC mass concentration data calculated by the method of the least squares (MLS) for the period 2008–2015. A dark grey slim line – the main approximation component (MH) of the data, a black bold line - MH combined with five harmonics, a grey slim line - an estimated trend function.

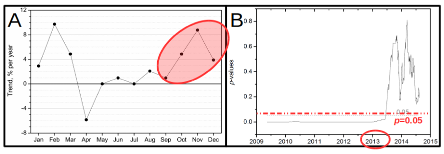

Fig. 2. Seasonal Mann-Kendall method (A) and t-test trend analysis (B) applied to eBC mass concentration data for the period of 2008-2015.

The MLS analysis has shown that the mean eBC concentration for the whole measurement period was 750 ng/m³. A positive annual linear trend for the whole period was estimated to range from +1.97% to +5.35% per year. The second order annual trend function (Fig. 1) estimated that the maximum eBC concentration was reached on January 2013 and was declining during the last years of the investigated period. Hovewer, the t-test showed that the trend is statistically significant only till 2014 (Fig. 2 B).
A seasonal pattern was observed with the highest eBC values (1170 ng/m³) in winter gradually declining to the minimum concentration (380 ng/m³) in summer. The seasonal Mann-Kendall test revealed that an increasing trend, above 2.5% per year, is characteristic of the cold period (from October to March) of the year. Negative Mann-Kendall trend was observed only in April. Data coverage for this month was low, therefore it should be disregarded.
Data selected for the Aethalometer model was selected to depict three main positions of the trend (Fig.1).

Four months during the cold season (2 in autumn and 2 in winter) were selected, in autumn increasing trends had been observed and in winter highest eBC concentrations prevail. For each month 5 weekdays and 2 weekend days were randomly selected.

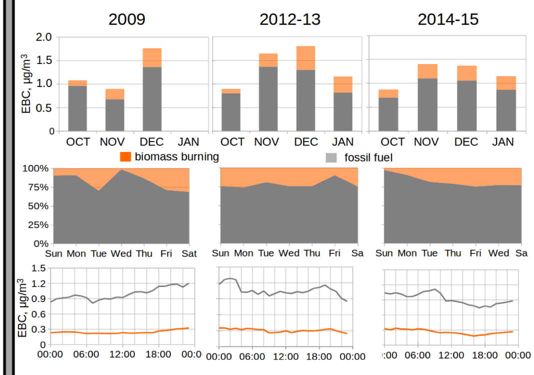

Fig. 4. EBC mass concentration contribution from fossil fuel (grey color) and biomass burning (orange) sources derived from Aethalometer model. First line depicts monthly, second – weekly and third – durnal variations of eBC.

Fossil fuel (FF) contributed 82% (SD 19%) of eBC at Preila measurement site during the cold period (Fig. 4). In days, when the eBC daily average was lower than 750 ng/m³ (annual mean for this site), the model occasionally overstimated FF contribution. December and November had the highest impact on the positive trend and FF contribution has increased in December by 1.25% per year (from 75 % to 81 % (SD 15%)). Diurnal variation of eBC concentration didn't reveal a clear pattern, which could be associated with traffic during the rush hours, however the situation of "no pattern" suggest that this pollutant was probably transported to the site by long-range air masses.

Conclusions

An increasing eBC trend was observed during period of 2008-2013 th in South-Eastern Baltic sea.
The highest contribution during the cold season was from fossil fuel sources.

References

Collaud Coen, M., Andrews, E., Asmi, A., ... & Laj, P., (2013). Atmos. Chem. Phys., 13, 869–894.

Virkkula, A., Mäkelä, T., Hillamo, R., Yli-Tuomi, T., Hirsikko, A., Hämeri, K., Koponen, I.K., Mä, T., Hä, K., 2007. J. Air Waste Manage. Assoc. 57(10), 1214–1222.

Sandradewi, J., Prévôt, A. S. H., Szidat, S., ... & Baltensperger, U. (2008). Environ. Sci. Technol. 42(9), 3316–3323.

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