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A European aerosol phenomenology -5: climatology of black carbon optical properties at 9 regional background sites across Europe

Marco Zanatta (1,2), Fabrizia Cavalli (3), Martin Gysel (2), Ernest Weingartner (4,2), Nicolas Bukowiecki (2), Jean Philippe Putaud (3), Thomas Müller (5), Urs Baltensperger (2), Paolo Laj (1), and the ACTRIS station leaders Team

(1) Univ. Grenoble Alpes/CNRS, Laboratoire de Glaciologie et Géophysique de l'Environnement, Grenoble, France(Marco.Zanatta@psi.ch), (2) Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, Villigen, CH-5232, Switzerland, (3) European Commission, Joint Research Centre (JRC), Institute for Environment and Sustainability (IES), Air and Climate Unit, via E. Fermi 2749, 21027 Ispra VA, Italy, (4) Institute for Aerosol and Sensor Technology, University of Applied Sciences, Windisch, Switzerland, (5) Leibniz Institute for Tropospheric Research, Permoserstrasse 15, 04318 Leipzig, Germany

A reliable assessment of the optical properties of atmospheric black carbon is of crucial importance for an accurate estimation of radiative forcing. In this study we investigate the spatio-temporal variability of the mass absorption cross-section (MAC) of atmospheric black carbon, defined as light absorption coefficient (σap) divided by elemental carbon mass concentration (mEC). σap and mEC have been monitored at supersites of the ACTRIS network for a minimum period of one year. The 9 rural background sites considered in this study cover southern Scandinavia, central Europe and the Mediterranean. σap was determined using filter based absorption photometers and mEC using a thermo-optical technique. Homogeneity of the data set was ensured by harmonization of the instruments deployed at all sites during extensive intercomparison exercises at the European Center for Aerosol Calibration. Annual mean values of σap at a wavelength of 637 nm vary between 0.75 - 1.6 Mm-1 in southern Scandinavia, 4.1 – 11 Mm-1 in central Europen and 2.3-2.8 Mm-1 in the Mediterranean region. Annual mean values of mEC vary between 0.75 and 1.6 μg m-3 in southern Scandinavia, 0.28-1.1 in Central Europe and British Isles, and 0.22-0.26 in the Mediterranean. Both σap and mEC in southern Scandinavia and central Europe have a distinct seasonality with maxima during the cold season and minima during summer, whereas at the Mediterranean sites an opposite trend was observed. Annual mean MAC values were quite similar across all sites and the seasonal variability was small at most sites such that a MAC value of 10$\pm$ 2.5 m2 g-1 (mean $\pm$ SD of station means) at a wavelength of 637 nm can be considered to be representative of the mixed boundary layer at European background sites. This is rather small spatial variability compared to the variability of values in previous literature, indicating that the harmonization efforts resulted in substantially increased precision of the reported MAC. However, absolute uncertainties of the reported MAC values remain as high as $\pm$40% due to the lack of appropriate reference methods.
The mass ratio between elemental carbon and non-light-absorbing matter (NAM) was used as a proxy for the degree of internal mixing of the BC containing particles, in order to assess the influence of mixing state on the MAC of BC. Indeed, the MAC was found to increase with increasing degree of internal mixing. This provides evidence that the lensing effect increases the absorption cross section of atmospheric BC to some extent.