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Direct Radiative Effect and Heating Rate of black carbon aerosol: high time resolution measurements and source-identified forcing effects

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Black carbon (BC) absorbs sunlight in the atmosphere heating it. However, up to now, heating rate (HR) calculations from the divergence of the net radiative flux with altitude or from the modelling activity are too sparse.
This work fills the aforementioned gap presenting a new methodology based on a full set of physical equations to experimentally determine both the radiative power density absorbed into a ground-based atmospheric layer (ADRE), and the consequent HR induced by the absorptive component of aerosol. In urban context, it is essentially related to the BC. The methodology is also applicable to natural components (i.e. dust) and is obtained solving the first derivative of the main radiative transfer equations. The ADRE and the consequent HR can be determined coupling spectral aerosol absorption measurements with the spectrally resolved measurements of the direct, diffuse downward radiation and the surface reflected radiance components. Moreover, the spectral absorption of BC aerosol allows its source apportionment (traffic and biomass burning (BB)) allowing the same apportionment on HR.
This work reports one year of high-time resolution measurements (5 min) of sunlight absorption and HR induced by BC aerosol over Milan. A unique sampling site was set up from March 2015 with: 1) Aethalometer (AE-31, Magee Scientific, 7-λ), 2) the Multiplexer-Radiometer-Irradiometer which detects downward and reflected radiance (350-1000 nm in 3648 spectral bands) coupled with a rotating shadow-band to measure spectrally-resolved global and diffuse radiation (thus direct), 3) a meteorological station (LSI-Lastem) equipped with 3 pyranometers (global, diffuse and refrected radiation; 300-3000 nm), a thermohygrometer, a barometer, an anemometer, 4) condensation and optical particle counters (TSI 3775 and Grimm 1.107), 5) low volume sampler (FAI Hydra dual sampler, PM2.5 and PM10) for sample collection and chemistry determination.
Results concerning the radiative power density absorbed by BC and the consequent HR allowed to determine: 1) the mean monthly values along one year (i.e. October: 14.5$\pm$0.2 mW/m3, 1.04$\pm$0.01 K/day of HR, 3.0$\pm$0.1 μg/m3 of BC); 2) the importance of the direct, diffuse and reflected radiation and thus of sky conditions (clear/cloudy) on the HR (i.e. October HR: 0.42$\pm$0.10 K/day for direct, 0.44$\pm$0.10 K/day for diffuse, 0.18$\pm$0.10 K/day for reflected); 3) the daily cycle influence of BC and radiation on HR; 4) the influence of anthropogenic activity studying the daily cycle along working and non-working days (i.e. September HR: 1.00$\pm$0.06 K/day for working days, 0.35$\pm$0.02 K/day for non-working days); 5) determine the radiative effect of traffic and BB sources of BC in function of the domestic heating operation. In particular, the domestic heating is allowed in Italy starting from 15th October: traffic BC for 1-15 and 15-31 October was 1.3$\pm$0.1 μg/m3 and 2.3$\pm$0.1 μg/m3 respectively, while BB BC was 0.7$\pm$0.1 μg/m3 and 1.5$\pm$0.1 μg/m3. In terms of HR, traffic BC for 1-15 and 15-31 October contributed with 0.46$\pm$0.01 K/day and 0.74$\pm$0.02 K/day while BB BC was 0.28$\pm$0.01 K/day and 0.61$\pm$0.02 K/day. All of the aforementioned results will be detailed in the presentation using the full set of data collected.