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Vertical profiles of BC direct radiative effect over Italy: high vertical resolution data and atmospheric feedbacks

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Black carbon (BC), and its vertical distribution, affects the climate. Global measurements of BC vertical profiles are lacking to support climate change research. To fill this gap, a campaign was conducted over three Italian basin valleys, Terni Valley (Appennines), Po Valley and Passiria Valley (Alps), to characterize the impact of BC on the radiative budget under similar orographic conditions.

120 vertical profiles were measured in winter 2010. The BC vertical profiles, together with aerosol size distribution, aerosol chemistry and meteorological parameters, have been determined using a tethered balloon-based platform equipped with: a micro-Aethalometer AE51 (Magee Scientific), a 1.107 Grimm OPC (0.25-32 μm, 31 size classes), a cascade impactor (Siuotas SKC), and a meteorological station (LSI-Lastem). The aerosol chemical composition was determined from collected PM2.5 samples. The aerosol absorption along the vertical profiles was measured and optical properties calculated using the Mie theory applied to the aerosol size distribution. The aerosol optical properties were validated with AERONET data and then used as inputs to the radiative transfer model libRadtran. Vertical profiles of the aerosol direct radiative effect, the related atmospheric absorption and the heating rate were calculated.

Vertical profile measurements revealed some common behaviors over the studied basin valleys. From below the mixing height to above it, a marked concentration drop was found for both BC (from -48.4±5.3% up to -69.1±5.5%) and aerosol number concentration (from -23.9±4.3% up to -46.5±7.3%). These features reflected on the optical properties of the aerosol. Absorption and scattering coefficients decreased from below the MH to above it (babs from -47.6±2.5% up to -71.3±3.0% and bsca from -23.5±0.8% up to -61.2±3.1%, respectively). Consequently, the Single Scattering Albedo increased above the MH (from +4.9±2.2% to +7.4±1.0%). The highest aerosol absorption was observed below the MH. The radiative power density absorbed into each atmospheric layer was normalized by the layer height to compare measurements taken at different sites with different vertical resolutions. The atmospheric absorption of radiative power below the MH ranged from +45.2±5.1 mW/m3 up to +103.3±16.2 mW/m3 and was ∼2-3 times higher than above MH. The resulting heating rate was characterized by a vertical negative gradient with increasing height, from -2.6±0.2 K/(day km) up to -8.3±1.2 K/(day km), exerting a negative feedback on the atmospheric stability over basin valleys, weakening the ground-based thermal inversions and increasing the dispersal conditions.