Comparison of three miniaturized aerosol-absorption instruments, under ambient and controlled conditions.

M. Pikridas[1], S. Bezantakos[1], G. Močnik[2, 3], C. Keleshis[1], F. Brechtel[4], E. Liakakou[5], F. Bastardi[2], L. Drinovec[2,3], A. Tsekeri[6], M. Vrekoussis [1,7, 8], G. Biskos[1], V. Amiridis[6], N. Mihalopoulos[1,5] and J. Sciare[1]

[1]*Energy Environment and Water Research Center, The Cyprus Institute, Nicosia 1645, Cyprus*
[2]*Aerosol d.o.o., 1000 Ljubljana, Slovenia*
[3]*Jozef Stefan Institute, 1000 Ljubljana, Slovenia*
[4]*Brechtel Mfg. Inc., 1789 Addison Way, Hayward, CA 94544 U.S.A.*
[5]*Institute for Environmental Research and Sustainable Development, National Observatory of Athens, 15236, Athens, Greece*
[6]*Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing, NOA, 15236, Athens, Greece*
[7]*Institute of Environmental Physics, U. of Bremen, Otto-Hahn-Allee 1, D-28359 Bremen, Germany*
[8] *Center of Marine Environmental Sciences - MARUM, D-28359 Bremen, Germany*

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Presenting author email: mpikridas@cyi.ac.cy

An intensive field campaign hosted by the National Observatory of Athens, aiming at characterizing the vertical distribution of absorbing aerosol, was held at Lofos Nymfon at the centre of Greece's capital, Athens, between 14-21 January 2016. Athens is an urban area, located in the southeast Mediterranean, having more than 4 million inhabitants.

The vertical profile of BC was measured under dry conditions using one commercial (AE51) and two prototype miniaturized instruments (Brechtel Inc. - 3-wavelength Model 9400 STAP; custom made Dual-Wavelength Prototype - DWP) using a multicopter (DJI Model S1000+) with a 2 kg payload. A total of 26 flights were performed reaching as high as 1 km above sea level. During 19th January 2016, flights were conducted almost every hour. The resulting profiles were compared against concurrent LIDAR and sun-photometer vertical absorption coefficient (β_{abs}) measurements using the GARRLiC algorithm (Lopatin et al., 2013). Even though the shapes of the measured and calculated profiles were in agreement, they differed by a factor of 3-5.

During each flight, the absorption instruments not involved in vertical profiling, measured the aerosol absorption at ground level in parallel with two commercially available instruments (Magee Scientific AE33; Thermo MAAP) allowing a comparison among them. STAP and DWP, exhibited excellent correlation against AE33 (R^2>0.90) shown in Fig. 1, while the commercially available AE51 performed poorer (R^2>0.75) because it operated at a face velocity of 0.5 m s^{-1}, lower by a factor of 3-9 compared to the other miniature absorption monitors. However, all monitors measured BC concentrations lower by 20-25% compared to the AE33 but within 5% to those measured by the MAAP. Additionally, all the miniature instruments agree, on average, within 4% with each other with respect to β_{abs}, but not with AE33 that measured β_{abs} values higher by a factor of 5 (Fig. 1).

Due to weight restrictions, STAP and DWP could not fly simultaneously. However, the AE51's low weight enabled the comparison under realistic conditions during 8 flights. Similarly to the ground measurements, all instruments agreed within 10% with respect to β_{abs} and BC mass, even though the correlation was poor (R^2>0.68). It should be noted that ground measurement comparison was conducted using the AE33 sampling resolution (1 min), while onboard simulations under higher (1 s) resolution.

Because ambient conditions did not allow the instrument comparison at concentrations exceeding 15 μg m^{-3}, several experiments with BC measurements ranging between 20-300 μg m^{-3}, were conducted under controlled (chamber) conditions using an AE33 as a reference and a kerosene burner that produced particles dominated by BC. Care was taken so that measurements corresponding to attenuation exceeding 0.1 were omitted from analysis. Similar to the ambient measurements, the correlation among all instruments was excellent (R^2>0.90) but all miniature instruments underestimated both the BC concentration and β_{abs} with respect to the reference (AE33). STAP, AE51, DWP β_{abs} reported values lower by 13%, 28% and 43% respectively, compared to the AE33. These results suggest that, under these extreme concentrations, the loading effect cannot be neglected even at low filter attenuation. DWP which incorporates the highest flow concentrated to the smallest spot area (face velocity equal to 4.7 m s^{-1}) exhibited the highest deviation.

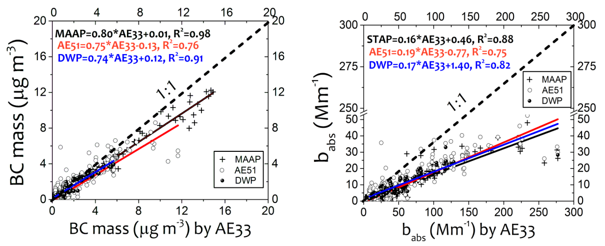

Figure 1. Comparison between aethalometer model AE33 and three miniaturized absorption instruments suitable for airborne measurements with respect to BC mass (left) and absorption coefficient at 880 nm (right) of ambient particles.

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