which cause more deviation in σ_{sca}, could have affected the σ_{abs} measurements since the particulate scattering causes apparent absorption and affects the multiple scattering in the filter. For example, the coarse particles (diameter > 1 µm) do not penetrate as deep in the filter as the fine-mode particles, which could possibly influence the C_{ref} values. In an ideal situation the PM_1 and PM_{10} absorption would have been measured by separate instruments.

Our observations underline the need for filter-loading correction, especially if one studies shorter time periods. For longer time periods (e.g., trend analysis or studies of seasonal variation), the effect of ATN on the variation smooths out, but for shorter time periods (e.g., case studies), the changing ATN can have a notable effect on the results if no filter-loading correction is applied. However, when not correcting for the filter-loading effect, the precision of the instrument and σ_{abs} or the BC concentration on average are reduced, which is why applying a filter-loading correction on filter-based photometers is always recommended.

4.3 Absorption Ångström exponent for different correction algorithms

The effect of the correction algorithms on α_{abs} was studied, and the average α_{abs} values for different correction algorithms of the AE31 and PSAP are presented in Fig. 6. This figure includes only parallel data from both the AE31 and the PSAP in order to avoid any differences caused by different time periods. For a comparison, α_{abs} was also determined for the "raw" PSAP data that were not corrected by any algorithms (i.e., σ_{ATN}; see Eq. 1). To have comparable α_{abs} values from the different instruments, Fig. 6 includes only overlapping AE31 and PSAP data from 2011–2015. Since the PSAP operates at three wavelengths (467, 530, and 660 nm), we determined the AE31-related α_{abs} in Fig. 6 by using only the wavelengths 470, 520, 590, and 660 nm of the AE31. The rest of the AE31 wavelengths were omitted from this comparison to minimize the effect of different wavelength ranges have on α_{abs} (for example, see Luoma et al., 2019: Table 1). α_{abs} was determined as a linear fit over all the selected wavelengths according to Eq. (16). Since Luoma et al. (2019) did not observe a big difference between the PM_1 and PM_{10} α_{abs}, we included both measurements in this comparison.

According to Fig. 6, the median values of α_{abs} varied notably between the different instruments and correction algorithms: the lowest median value of α_{abs} was 0.93, and it was measured by the AE31 and corrected by CC2010; and the highest median value of α_{abs} was 1.54, and it was measured by the PSAP and corrected by V2010. The difference between the highest and lowest median values of α_{abs} was about 1.7-fold. The correction algorithms were applied to each wavelength separately, and therefore the correction algorithms affected the wavelength dependency of the derived σ_{abs}. The scattering and loading corrections are different for each wavelength because for example σ_{sca}, ω, ATN,

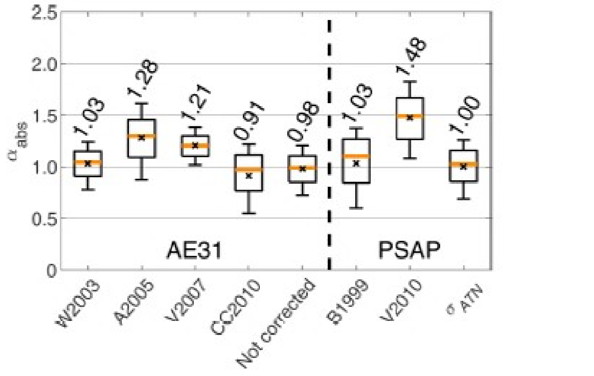

Figure 6. The absorption Ångström exponent (α_{abs}) for all the different AE31 and PSAP correction algorithms. The orange line in the middle of the box is the median; the black circle is the mean; the edges of the boxes represent the 25th and 75th percentiles, and the whiskers represent the 10th and 90th percentiles of the data. The values given above each box show the corresponding median values.

and Tr, which are used in the algorithms, are wavelength dependent. For the AE31, we studied the same five correction algorithms as in Sect. 4.1. The lowest median α_{abs} values were observed for the non-corrected data ($\alpha_{abs,AE,NC}$) and for data that were corrected with the CC2010 and W2003 algorithms ($\alpha_{abs,AE,COL}$ and $\alpha_{abs,AE,WEI}$). The median α_{abs} values for the data corrected with the A2005 and V2007 algorithms ($\alpha_{abs,AE,ARN}$ and $\alpha_{abs,AE,VIR}$) were higher at 1.20 and 1.19, respectively.

A2005 was the only algorithm that assumed a wavelength-dependent C_{ref}. Since C_{ARN} increased with wavelength (i.e., bigger correction due to multiple scattering at higher wavelengths), taking the wavelength dependency of C_{ref} into account increases $\alpha_{abs,AE,ARN}$ compared to other algorithms. The correction factor of the V2007 algorithm depended on the difference between the ATN of loaded and clean filter spots. Most of the time ATN increased faster at short wavelengths than at long wavelengths, so the difference between the ATN of the loaded and clean filter spots was higher than for longer wavelengths. Therefore, the filter-loading correction was bigger for shorter wavelengths, and after the correction the difference between the σ_{abs} values at different wavelengths increased, increasing α_{abs} as well.

For the PSAP data, the α_{abs} values were generally a little higher compared to the AE31-derived α_{abs}. The lowest PSAP-derived median value for $\alpha_{abs,PSAP,NC}$ was 1.01, which resulted from data that were not corrected by any algorithm. B1999 resulted in a median $\alpha_{abs,PSAP,BON}$ value of 1.04, and V2010 produced the highest $\alpha_{abs,PSAP,VIR}$ overall, which was 1.48. A similar order of the average α_{abs} values from different algorithms was observed by Backman et al. (2014) at an urban station in Elandsfontein, South Africa. For a data set measured off the east coast of the United States on a research ship, Backman et al. (2014) also reported the highest α_{abs} for V2010. These results are consistent with