

**General Comments:**

**Reviewer:** *This paper is a closure study. There are few new concepts, ideas, or methods presented. The aerosol of the North China Plain has been studied previously. The work, however, utilizes high quality aerosol measurements and the closure study was performed with great care to detail. The measurements are in an important aerosol source region and will be of use to modelers. It is important to get quality data such as these into the refereed literature. Therefore the paper deserves to be published in ACP.*

**Response:** Thanks for the comments.

**Specific Comments:**

**Reviewer:** *p. 9573, MAAP absorption measurement: Assumes a mass absorption efficiency (MAE) of  $6.6 \text{ m}^2 \text{ g}^{-1}$ . This the "standard" MAE recommended by the manufacturer? Aerosols in China may have quite different optical properties than aerosols in Europe or the US. Have you tried to determine the site-specific MAE for your region? Can you place an uncertainty on this number?*

**Response:** The MAE of  $6.6 \text{ m}^2 \text{ g}^{-1}$  is used in the data processing in the MAAP (Instruction Manual for Model 5012 Multi Angle Absorption Photometer, 1 Dec 2003, p. 8-2). The MAAP measures the light transmission and reflection by the filter tape, thus yields the absorption coefficient. To report the BC mass concentration, a value ( $6.6 \text{ m}^2 \text{ g}^{-1}$ ) of MAE was used in the data processing of the instrument. Therefore, the accuracy of MAE only affected the accuracy of the BC mass concentration reported by MAAP, rather than the absorption coefficient calculated with  $\sigma_{\text{ap}} = \rho_{\text{BC}} \cdot \text{MAE}$ .

However, since the BC mass concentration was also used in this paper, it is necessary to evaluate the MAE, as recommended by the reviewer. In the HaChi campaign, a 10-stage Berner Impactor was applied to investigate the aerosol composition including the element carbon. The sampling periods were 11:00AM-5:00PM and 8:00PM-2:00AM for everyday. To give an estimation of the MAE for our measurement, the EC mass concentration sampled by the Berner Impactor was compared with the aerosol absorption coefficients measured at the same time by MAAP. As shown in Fig. 1, the dots are located around the dash line which relates  $\text{MAE} = 6.6 \text{ m}^2 \text{ g}^{-1}$ . The linear regression gives a slope of 7.01 as the best fit, which is very close to the standard MAE. Therefore, using the standard MAE recommended by the manual is appropriate in this region.

The MAE might be influenced by the particle size, the particle shape, as well as the mixing state of BC and other components. All these factors, especially the mixing state, might change via time in the same region, resulting the changing of MAE. Therefore, the correlation coefficient between the absorption coefficient and the EC mass concentration is 0.7488, which is a little low. Due to the uncertainties of the measured EC mass concentration, we think that it is better to use the standard MAE rather than the fitted MAE. So far, it is difficult to place an uncertainty of the MAE by the comparison shown as Fig. 1, because it is difficult to determine the contributions of the uncertainties of measured EC mass concentration to the uncertainty of MAE.

To make clear of this, a sentence "The mass absorption efficiency of  $6.6 \text{ m}^2/\text{g}$  has been validated by the comparison between the impactor-derived elemental carbon mass concentration and the MAAP measurements." has been added in section 2.3.

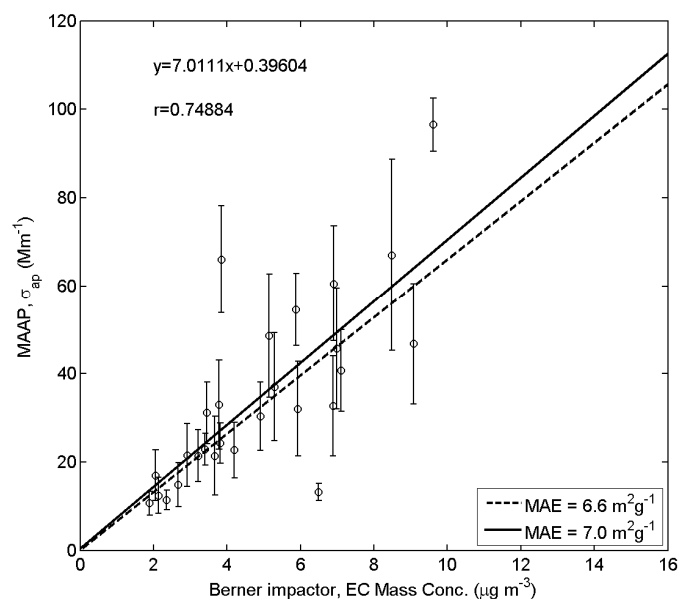


Fig. 1. Comparison of EC mass concentration sampled by BernerImpactor and the aerosol absorption coefficients ( $\sigma_{ap}$ ) measured at the same time by MAAP. The error bar presents the standard deviation of the  $\sigma_{ap}$  measured during the sampling periods of BernerImpactor.

**Reviewer:** p. 9573, Line 20: *Other types of sampling line losses (e.g., electrostatic losses) were ignored? Was conductive tubing used in all portions of the inlet system?*

**Response:** All the tubing, including the bends and valves, used in the inlet system was conductive tubing. Therefore, the main losses were diffusion losses, gravitational losses and impaction losses, which had been corrected. To make clear of this, a sentence “The electrostatic losses were ignored, since conductive tubing was used in all portions of the inlet system.” has been added in section 2.4.

**Reviewer:** p. 9574, Lines 2-5: *OC can have light absorbing components (e.g., HULIS). To neglect these may be a mistake.*

**Response:** As mentioned in the 2<sup>ed</sup> response, the MAAP measures the light transmission and reflection by the filter tape, thus yields the absorption coefficient. So the absorption coefficients yielded from MAAP include the contribution from all light-absorbing components, but not only BC. So the absorption coefficients reported in this paper would be correct even if there is light-absorbing OC.

However, the light-absorbing OC may cause an overestimation of the BC mass concentration reported by MAAP, since all the light-absorbing material is “considered” as BC in the data processing in MAAP. We cannot provide the specific influence of OC on the absorption coefficients. However, from Fig. 1 it can be seen that the ratios of measured EC mass concentrations to the absorption coefficients are close to the standard MAE recommended by the manual of MAAP. It means that most of the light absorption is contributed by BC, while the influence of OC may not be significant.

Also, the sentences “It should be noted that OC may also have light-absorbing components, such as HUmic-Like Substances (HULIS) (Graber et al., 2006), thus causes a bias in the BC mass

concentration reported by MAAP. This possible source of uncertainty is not considered in this study.” has been added in section 4.2.2.1 paragraph 2 to clarify this.

**Reviewer:** *p. 9574, Lines 13-15: BC mass size distribution (normalized) in Wuqing is assumed to be the same as that in Yufa. Wuqing might be influenced more by fresh Tianjin emissions than Yufa. Any comment on this? Any reason to discount this possibility?*

**Response:** From the wind frequency distribution, it can be noted that E-SE wind is not frequent in either spring or summer. As shown in section 4.1.1, the  $\sigma_{sp}$  and  $\sigma_{ap}$  measured in Wuqing and Yufa are very similar. A new research on emission calculation by Xu et al. (to be submitted to this special issue of ACPD) suggests that the average BC contribution from Tianjin to local concentrations in Wuqing during the summer period is about 10%.

**Reference:**

Xu, W. Y., Zhao, C. S., Liu, P. F., Ran, L., Ma, N., Deng, Z. Z., Lin, W. L., Yan, P. and Xu, X. B.: A new retrieval approach of emissions based on trajectory modeling and its application to estimating pollutant emissions in the North China Plain, to be submitted to ACP, 2011.

**Reviewer:** *p. 9578, Lines 4-6: AAE of 1.0 is used, based on an old reference using aerosol measurements from pristine regions. AAE can be quite variable, especially if the aerosols are internally mixed. Are there any historical multiple-wavelength light absorption or AAE data from this region? These data could be used to determine whether an AAE of 1.0 is reasonable for this region. At the least the authors should list a more appropriate reference.*

**Response:** Thanks for the valuable comments. We have modified the parts relating to the calculated SSA. Since there is no reliable historical multiple-wavelength light absorption data, to avoid the large uncertainty in the SSA data, all the SSA was presented at wavelength of 637 nm instead of 550 nm in this paper. The sentence “To calculate  $\omega$ , a wavelength correction for aerosol absorption is applied to the measured  $\sigma_{ap}$  using an empirical approach,  $\sigma_{ap} \propto \lambda^\beta$ , with the absorption exponent  $\beta=1$  (wavelength  $\lambda$  in the interval 0.45–0.70  $\mu\text{m}$ ) (Bodhaine, 1995)” has been replaced with “To calculate  $\omega$  at the wavelength of 637 nm, a wavelength correction is applied to the measured  $\sigma_{sp}$  using an empirical approach,  $\sigma_{sp} \propto \lambda^\alpha$ . The Ångström exponent ( $\alpha$ ) is yielding from the measured  $\sigma_{sp}$  at the wavelength of 550 nm and 700 nm.” All the corresponding tables and figures have also been updated with the new values.

**Reviewer:** *p. 9578, Line 7: These SSA values are not consistent with the findings of Yan et al. (2008) at SDZ. Are the aerosols really that different at SDZ and Wuqing? If so, it is difficult to rationalize the idea that the aerosols of the NCP are similar (see comment above for p. 9574, Lines 13-15).*

**Response:** Shangdianzi (SDZ, 40°39'N, 117°07'E, 239.9ma.s.l.) is a regional background station without any significant anthropogenic pollution, located in the rolling hills 150 km northeast of the urban areas Beijing (see Fig. 2). It can be seen that the SDZ station is at the north edge of the North China Plain. The major cities and industrial areas with high pollution emissions are in the south of SDZ, while the areas in the north of SDZ are much less inhabited and the industrial activities are less prevalent (Yan et al., 2008). Therefore, only when the dominant wind comes

from the south, the observations at SDZ are representative for the North China plain. This also can be seen in the average AOD distributions (Fig. 3). The average AOD at SDZ is close to that of the clean area in the north China, but much lower than the average AOD of the North China Plain.

However, the Wuqing site and Yufa site are among the major cities and industrial areas in the North China Plain. The observations are representative of the average level of pollution in this region; this can be seen in the average AOD distribution. Also, the average  $\sigma_{sp}$ ,  $\sigma_{ap}$  and SSA measured in Wuqing site and Yufa site are very similar, but different from that measured in SDZ.

**Reference:**

Yan, P., Tang, J., Huang, J., Mao, J. T., Zhou, X.J., Liu, Q., Wang, Z. F., and Zhou, H. G.: The measurement of aerosol optical properties at a rural site in Northern China, *Atmos. Chem. Phys.*, 8, 2229–2242, doi:10.5194/acp-8-2229-2008, 2008.

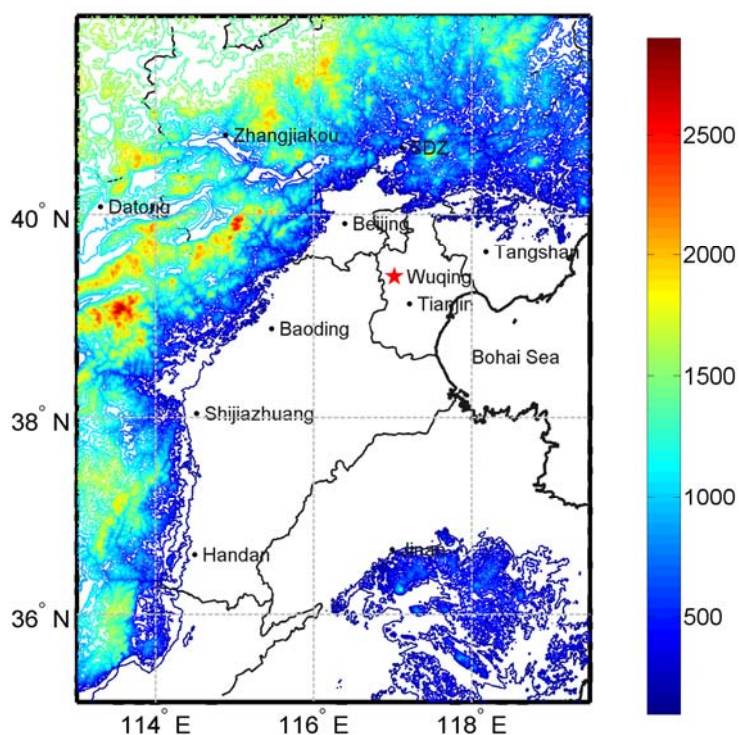


Fig.2 Contour map of the North China Plain. Colors stands for the elevation.

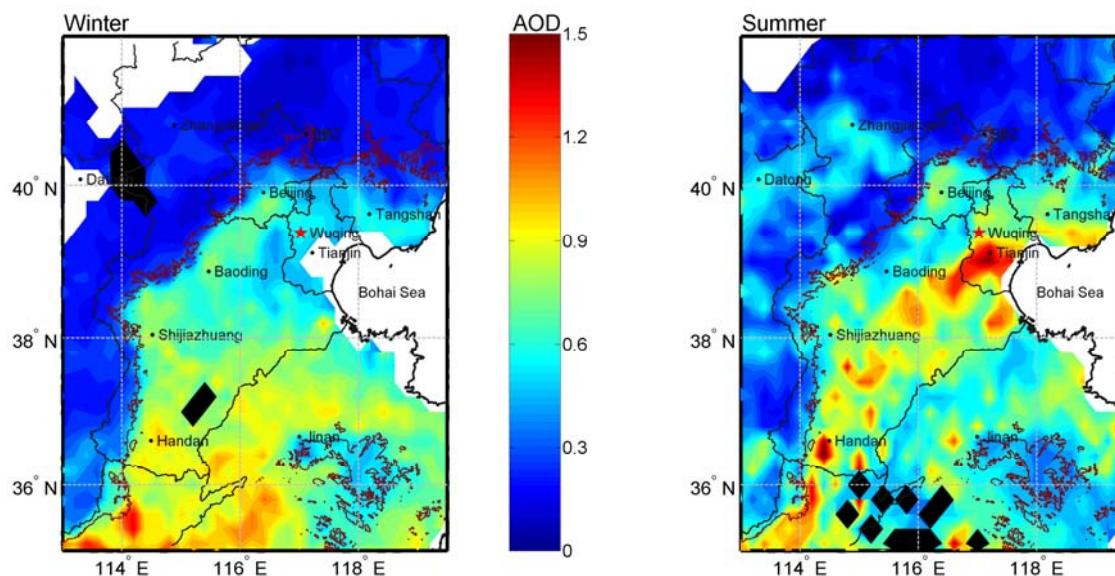


Fig. 3 The average AOD distributions in the North China Plain for spring and summer, respectively.

**Reviewer:** p. 9582, Lines 22-23: *Absorption enhancement of 2.32? This is quite large! Has an absorption enhancement for internally mixed vs. externally mixed aerosols of this magnitude ever been observed before? If so, please reference. If not, you should emphasize this finding.*

**Response:** Cheng et al. (2006) found a similar absorption enhancement, which is about 2.3, for internally mixed vs. externally mixed aerosols in an optical closure study at Xinken in Pearl River Delta of China (Cheng et al., 2006). As recommended by the reviewer, a sentence “This result is in a good agreement with the studies by Cheng et al. (2006). Wex et al. (2002) reported a lower factor, which is 2.05, at a European site.” has been added in section 4.2.1.

**Reference:**

Cheng, Y. F., Eichler, H., Wiedensohler, A., Heintzenberg, J., Zhang, Y. H., Hu, M., Herrmann, H., Zeng, L. M., Liu, S., Gnauk, T., Brüggemann, E., and He, L. Y.: Mixing state of elemental carbon and non-light-absorbing aerosol components derived from in situ particle optical properties at Xinken in Pearl River Delta of China, *J. Geophys. Res.*, 111, D20204, doi:10.1029/2005JD006929, 2006.

Wex, H.: Closure and sensitivity studies on physical parameters of rural continental aerosols, Ph.D. Thesis, Leipzig University, 2002b.

**Reviewer:** p. 9585: *Good discussion of the uncertainties in the calculated parameters. +/- 30% is a large range - perhaps not surprising that the measurements agree with the calculations. This is a typical finding in carefully performed closure studies... when all uncertainties are considered and accounted for, total uncertainties are large and calculated and measured values often agree (within the envelopes of the uncertainties).*

**Response:** Thanks for this comment.

Technical Comments:

**Reviewer:** p. 9578, Line 12-13: *Incomplete sentence.*

**Response:** Thanks for point out this mistake. The sentence “The  $\omega$  in Wuqing is relatively low compared to the values retrieved through AERONET for the northern hemisphere (0.85-0.95) (Dubovik et al., 2002). Since our measurements are controlled at a RH below 30%.” has been replaced with “The  $\omega$  in Wuqing is relatively low compared to the values retrieved through AERONET for the northern hemisphere (0.85-0.95) (Dubovik et al., 2002), since our measurements are controlled at a RH below 30%.”