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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Dust events in Beijing, China (2004–2006): comparison of ground-based measurements with columnar integrated observations" *by* Z. J. Wu et al.

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Response to the reviewer 1 The paper presents discussion on the dust events observed in Beijing, China during 2004 – 2006 and compared few parameters observed from ground and AERONET. I would like to bring out following comments; I hope the authors may address these comments for smooth reading of their paper. == (1) Abstract – There is need to define spring months in the abstract. The abstract needs to be rewritten, authors may consider to quantify some of the parameters, e.g.

strong wind speeds? How strong?

Response: In this study, the spring months include March, April, and May. In contrast to type 2, type 1 dust events took place under larger wind speeds. On average, the wind speeds for type 1 are larger than 4 m s-1. These will be clarified in the abstract.

Modification in the MS: (a) "during dust events in the springs (March, April, and May) of 2004-2006 in combination with AERONET sun/sky radiometer data."

(b) "Dust particles dominated the total particle volume concentration (3-10000 nm) (over 70%) for the dust events in type 1, which happened under strong wind speeds (on average, > 4 m s-1)."
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(2) In the abstract, authors have mentioned two different types of dust based on the aerosols index and aerosol optical depth. For the benefit to the readers, aerosol index must be defined. The characteristics of dust events in terms of aerosol index and aerosol optical depth must be given separately.

Response: In this study, the categorization is based on the particle number size distributions and local weather conditions, not the aerosols index and aerosol optical depth. But, these parameters support the categorization.

The aerosol index is a measure of how much the wavelength dependence of backscattered UV radiation from an atmosphere containing aerosols (Mie scattering, Rayleigh scattering, and absorption) differs from that of a pure molecular atmosphere (pure Rayleigh scattering) (http://www.knmi.nl/omi/research/product/aerosol/ai.html). In this study, the TOMS AI is used as a qualitative indicator of ultraviolet absorbing aerosols, which is the same with other studies (Herman et al., 1997; Torres et al., 1998; Dey et al., 2004). It has already been pointed out in the text. Considering AI is commonly used in the scientific articles, the detailed definition for AI is not presented in the text in order to shorten the manuscript.

ACPD

9, C4210–C4217, 2009

Interactive Comment

The AI images are used to understand the sources of dust particles. It is difficult to characterize the AI images and distinguish them between type 1 and type 2.
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(3) The AERONET provides number of parameters and authors have included AOD at 440 nm and normalized particle volume. The authors may consider to give plots showing the changes in AOD, angstrom exponent, and real and imaginary parts of the Refractive Index which will provide characteristics of the two type of dust events. These parameters are important in the evaluation of climate effect due to dust.

Response: The variations in AOD and angstrom exponent during dust events have already been shown in the MS. The discussions about real and imaginary parts of the RI will be added into the text.

Modification in the MS: Figure 12 shows the statistical summary of the refractive index (real part: $n(\lambda)$ and imaginary part: $k(\lambda)$) at the wavelength of 441, 675, 870, and 1020 nm for type 1, type 2, and heavy pollution periods. Typically, the higher $n(\lambda)$ and lower $k(\lambda)$ during dust events are observed compared to non-dust days (Dey et al., 2004; Prasad and Singh, 2007). This is consistent with our observations, as showed in Fig. 12. The mean $n(\lambda)$ values for type 1 and 2 are significantly higher than those for heavy pollution periods. An inverse pattern is observed for $k(\lambda)$ (Fig. 12 b). In contrast to type 1, the lower $n(\lambda)$ and higher $k(\lambda)$ are found for type 2 due to the higher contribution of urban aerosols in type 2.
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(4) Currently, it is very difficult to visualize the background value of aerosols parameters over Beijing when the dusts are absent. The authors may consider to show aerosol parameters obtained by AERONET for the whole year to visualize the effect of dusts. It is not very clear, if the authors have analyzed radio-sounding data over Beijing or elsewhere to study the stability of the boundary layer!

Response: There are 18 events have been identified in Beijing over the three years (2004-2006), of which 13 events took place in the spring of 2006. In this connection, we only analyze the seasonal variations of optical properties in 2006 for finding out the influences of dust events over the year. The discussions will be presented in the MS.

The analysis on radio-sounding data may not be enough to see the boundary layer height, but at least it can act as an evidence to support the categorization because the significant differences in the potential temperature profiles between type 1 and type 2 are observed. This is the goal for presenting the radio-sounding data in this study.

Modification in the MS: The mean AOD, Ångström exponent, and refractive index (RI) during the dust events are shown in table 2. In order to gain insight into the effects of the dust events over year, the average columnar optical parameters in the four seasons of 2006 are presented in the last four rows of table 2. Here, the four seasons were classified as spring (March-May), summer (June-August), fall (September-November), and winter (December-February). It was found that the lowest mean Ångström exponent was observed in spring, indicating a relatively high ratio of large particles to small particles due to dust loading in this season. The highest AOD and Ångström exponent were found during the summertime, implying that the AERONET sites in Beijing were mainly affected by the fine urban aerosols, but not by the coarse-mode particles. The similar results were also reported by Kim et al. (2007). The highest mean n(λ) and the lowest mean k(λ) were observed in spring of 2006. A similar seasonal variation of RI was reported by Yu et al. (2009) based on the AERONET data spanning from 2001 to 2007.
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(5) The authors have shown back-trajectories of the dust events but it is not very clear to visualize to find out the source of dusts. Based on radio-sounding data, authors may include discussion about the changes in the temperature at different pressure level due to dust events.

Response: To do this, the detailed information on the changes in radio-sounding parameters when dust storm occurred in the source regions is necessary. But, obtaining this information is impossible. So, the changes in the temperature and relative humidity along the track of back-trajectory do not help to identify the source regions, accurately.

ACPD

9, C4210–C4217, 2009

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(6) The present structure of the paper needs to be restored so that readers must see the characteristics of the aerosol parameters over the years and changes associated with the dust events. A detailed table showing changes in the aerosol parameters due to each dust events may be given which are easily available through AERONET.

Response: The characteristics of seasonal variations in particle number size distributions were discussed in elsewhere (Wu et al., 2008). Here, the authors don't want to present them, again. Regarding the columnar optical parameters, they will be added into the MS (see the previous response). To follow the reviewer's suggestion, a table (Table 2) containing the mean optical parameters for each dust event is shown in the text.

Modification in the MS: In table 2, a significant difference in the columnar particle optical properties between DS2, DS3, DS11, DS16, and DS18 and other events is found. It supports the above-mentioned categorization of dust events (type 1 and type 2). In the following sections, the particle number size distributions and particle optical properties for the two types will be discussed in detail.

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Reference:

Dey, S., Tripathi, S.N., Singh, R.P., Holben, B.N., 2004. Influence of dust storms on the aerosol optical properties over the Indo-Gangetic basin. Journal of Geophysical Research-Atmospheres 109. Herman, J.R., Bhartia, P.K., Torres, O., Hsu, C., Seftor, C., Celarier, E., 1997. Global distribution of UV-absorbing aerosols from Nimbus 7/TOMS data. Journal of Geophysical Research-Atmospheres 102, 16911-16922. Torres, O., Bhartia, P.K., Herman, J.R., Ahmad, Z., Gleason, J., 1998. Derivation of aerosol properties from satellite measurements of backscattered ultraviolet radiation: Theoretical basis. Journal of Geophysical Research-Atmospheres 103, 17099-17110. Wu, Z.J., Hu, M., Lin, P., Liu, S., Wehner, B., Wiedensohler, A., 2008. Particle number

ACPD

9, C4210–C4217, 2009

Interactive Comment

size distribution in the urban atmosphere of Beijing, China. Atmospheric Environment 42, 7967-7980.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 11843, 2009.

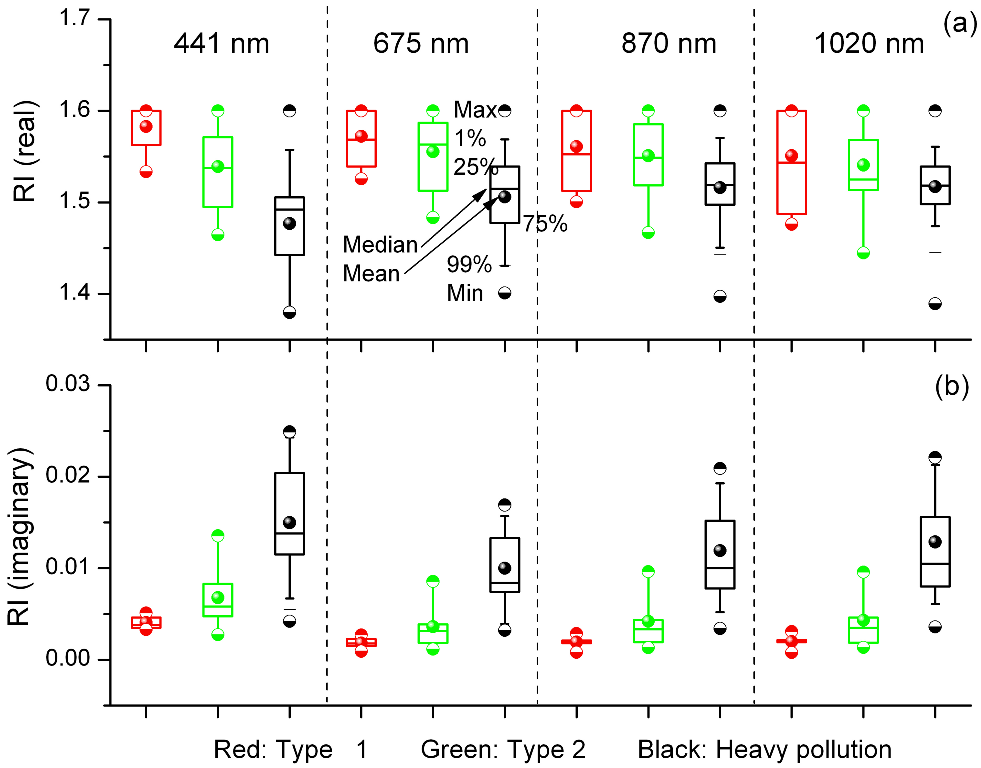

Fig. 1. Figure 12: Statistical summary of real and imaginary parts of refractive index at the wavelength of 441, 675, 870, and 1020 nm for type 1, type 2, and heavy pollution periods

ACPD
9, C4210–C4217, 2009

Events	AOD	Ångström	RI (n(λ))	RI (k(λ)) (×10^{-3})
DS1	0.38	0.11	---	---
DS2	1.31	0.11	1.54/ 1.54/1.52/1.50	5.1/1.8/2.1/2.1
DS3	1.31	1.05	1.51/1.54/1.55/1.54	11.6/7.7/9.1/9.0
DS4	---	---	---	---
DS5	0.41	0.20	---	---
DS6	0.90	-0.01	1.60/1.57/1.55/1.54	4.0/0.9/0.8/0.8
DS7	0.19	0.33	---	---
DS8	---	---	---	---
DS9	---	---	---	---
DS10	0.44	0.20	---	---
DS11	1.62	0.41	1.56/1.57/1.57/1.56	5.4/2.7/3.1/3.3
DS13	---	---	---	---
DS14	0.34	0.25	---	---
DS15	1.12	-0.03	1.60/1.60/1.60/1.60	5.4/2.7/3.1/3.3
DS16	1.24	0.51	1.55/1.57/1.58/1.57	6.9/3.6/4.0/4.3
DS17	1.38	0.04	1.55/1.53/1.52/1.48	3.5/1.8/1.9/2.0
DS18	2.52	0.51	1.48/1.48/1.48/1.47	4.7/2.1/2.7/2.8
Spring	1.04	0.69	1.52/1.55/1.56/1.56	10.4/7.0/8.3/8.8
Summer	1.18	1.19	1.44/1.46/1.47/1.48	11.4/9.0/10.0/10.5
Fall	0.92	1.09	1.49/1.51/1.51/1.53	16.8/14.1/14.2/17.1
Winter	0.65	1.08	1.49/1.52/1.53/1.53	17.9/10.5/11.8/12.8

Fig. 2. Table 2: Mean columnar optical parameters during the dust events and in four seasons of 2006.

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9, C4210–C4217, 2009

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