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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Study of columnar aerosol size distribution in Hong Kong" *by* X. Yang and M. Wenig

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Answers to referee 1

We would like to thank the reviewer for his/her very useful comments and suggestions.

The major comments refer to the question whether the meteorological condition variation from July to November affect the measured local aerosols and our data analysis. We think there is influence on local aerosol from the wind direction and relative humidity variation. Study of aerosol variation on different seasons and transported aerosol combining backward trajectories could help more on understanding aerosol characteristics and sources, and we actually have ongoing work in this area. Nevertheless, the observed middle mode which probably comes from aerosol hygroscopic growth and coagulation occurred through the whole season from July to November. Concerning the two mechanisms, both processes could cause the observed systematic shift of aerosol size distribution under different aerosol loadings and Angstrom exponent conditions, and the latter process depends on aerosol concentrations rather than the relative humidity. Furthermore, the absolute variations of relative humidity on different months are not significant. For a more detailed explanation, we address your comments one by one as follows.

The data in the study covered the period July to November in a number of years. The meteorological conditions in July to September and those of October to November could be quite different. The former is more the more humid summer with southerly airflow. The later is drier autumn with continental, northeast monsoon. Even in the summer time, the effect of tropical cyclones on the airmass could be significant and high AOD days could occur in northerly winds associated with tropical cyclones, when the air could be rather dry. As a first step of the analysis of the AOD data, the paper could be accepted as it is. But the authors are encouraged to carry out further study in the future to distinguish between maritime and continental airstream conditions, by referring to the prevailing wind direction and the RH in Hong Kong. The authors are encouraged to mention this approach to further study (and thus limitation of the present study) in the present paper.

The aerosol variations on the two periods, July to September and October to November, are presented in Figure 1 and Figure 2. The middle mode is observed and it becomes more significant under high aerosol loadings and Angstrom exponent.

The monthly mean relative humidity in the four years is presented in Table 1. The data come from the Hong Kong Observatory. Overall, the local relative humidity remains at a high level (a mean value larger than 75% and a minimum value larger than 60%) and the absolute variation is small. So it will be added into the paper for better understanding the atmospheric conditions and estimation of its impact on aerosols.

Concerning the aerosol hygroscopic growth and coagulation, there are many papers on presenting the observed shifting of aerosol size distribution and third mode and they usually attribute them to the hygroscopic growth and coagulation using the sun-sky radiometer measurements (Dubovik et al., 2002; Eck et al., 2001, 2003a, 2003b; Reid et al.,1998, 1999; Singh et al., 2004). For example, the pronounced third mode is observed in the urban-industrial area by Singh et al. (2004), where the relative humidity is described as ranging 25-50% in the dry season and 60-90% in the wet season (more specific information is not available from that paper). The hygroscopic growth from fine aerosol is considered as the main cause since the relative humidity becomes more pronounced in the wet season. The shifting of fine aerosol growth towards larger size under higher aerosol loadings is also observed in the urban-industrial areas like Mexican City by Dubovik et al. (2002), which are attributed to the aerosol hygroscopic growth and coagulation, but it is also specified that the shifting under higher aerosol loadings with low relative humidity (50-60%) are observed on urban and biomass burning sites and therefore that the high relative humidity is not a necessarily primary factor. Baumgardner et al. (2000) studied the urban aerosol in Mexican City and assumed that the aerosol becomes hydrated when relative humidity is greater than 60%. It is admitted that the aerosol evolution mechanism underlying the phenomenon is hard to be clarified using solely remote sensing technology, and therefore there are studies using laboratory chamber (like some locally works done by Alex et al., 2008) and modeling to study the aerosol hygroscopic growth and coagulation (Jacobson and Seinfeld, 2004). Those studies could help our understanding, but on the other hand, do not provide the columnar aerosol size information. According to Figure 1 and Figure 2, the middle mode is more pronounced from July to September, which indicates the higher relative humidity variation facilitate aerosol growth. But the persistent middle mode through the whole season could be attributed to the coagulation factor and the fact the relative humidity is high enough, which is a very interesting finding.

Even in the summer time, the effect of tropical cyclones on the airmass could be sigificant and high AOD days could occur in northerly winds associated with tropical cy-

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clones, when the air could be rather dry.

The sun-sky radiometer can track the sun and works normally under sunny days and would stop in rainy days. When the weather is heavily cloudy, the sun-sky radiometer stops data logging. Moreover, when implementing the data inversion process, a cloud screening algorithm used in AERONET in used (Smirnov et al., 2000). A maximum 5% threshold that requires the reconstructed radiance to be close to the measured radiance is used plus the described filtering threshold. Overall, those hardware and software ways help together to mitigate the cloud influence.

(a) Section 2.2, second paragraph: about the modified Langley method - any reference? Is it sufficient to determine the calibration constant for the instrument every year? What's the recommendation from the instrument manufacturer?

The modified Langley method is used in all papers (Carmine et al., 2005; Highwood et al., 2003; Kaufman et al., 1994; Kim, et al., 2004; Nakajima et al., 2003; Zhen et al., 2008) which use the same instruments and inversion algorithm as far as we know. The instrumental manufacturer did not specify the inversion details and told us to read corresponding papers. More description on the instrument and inversion algorithm could be found in papers here (Campanelli et al., 2007; Nakajima et al., 1996; Tonna et al., 1995). In our paper, a detailed description on using the inversion algorithm and on the filter procedure to screen out cloud-contaminated data is given.

(b) Section 3.1, second paragraph: the use of daily mean AOD for comparison with MODIS AOD sounds a little bit odd. Any data to support the use of daily mean AOD instead of the AOD near the satellite overpass time? What would the comparison result become when AOD at satellite overpass time is considered? Moreover, at the end of the paragraph, it has been mentioned about the single pixel vs. mean pixel. Glad to see the single pixel AOD - instrument AOD comparison as well.

Figure 3 is the previous scattergrams of mean-pixel MODIS AOD versus the daily mean sun-sky radiometer AOD. Figure 4 presents the scattergrams of mean-pixel MODIS

AOD versus the mean AOD from sun-sky radiometer 2-hour before and after the Terra passing over Hong Kong (9:00 – 13:00 local time). It has better correlation, R = 0.926 compared previous 0.86. The coinciding days are 133, whereas there are 153 coinciding days when using daily mean sun-sky radiometer AOD. We used the daily mean plot in order to present more data, so the earlier plot will be replaced by Figure 4 for the new revised paper. Figure 5 shows the scattergrams of single-pixel MODIS AOD versus the mean AOD from sun-sky radiometer 2-hour before and after the Terra passing over Hong Kong (9:00 – 13:00 local time). The data is rather limited, only 25 days, because single pixel AOD from the MODIS are usually unavailable. The small slope here in Figure 5 is due to the limited data number, which could accompany with larger uncertainty. This can be found by Figure 6, which shows the corresponding mean-pixel MODIS AOD versus sun-sky radiometer, where the mean-pixel MODIS AOD is the MODIS data in the same day with the single-pixel data. The slope here is also small, whereas such slope has larger value when comparing more data as shown in Figure 4. In fact, there are only 26-day available for the single-pixel data, as shown in Figure 7, which denotes the scattergrams of MODIS single-pixel AOD versus MODIS mean-pixel AOD. For more comparison, the MODIS single-pixel data and corresponding mean-pixel AOD are also compared with the daily mean sun-sky radiometer data instead of using 4-hour mean radiometer data, which are shown in Figure 8 and Figure 9.

(c) Section 3.1, third paragraph: for the benefit of the readers, please mention that the instrument – AERONET comparison in October to November only covers the drier season. The authors may like to include some meteorological parameters in this period, such as prevailing wind and RH, to illustrate the limitations of the comparison.

We would specify this point and it would become clear after adding the relative humidity data (Table 1).

(d) Section 3.3, fifth paragraph: as said in the major comment, there could be significant variation of the RH in the study period of July to November. Better to present a

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table showing the RH variation in the study period to support that hygroscopic grow of aerosol is a major factor.

Explained above. We added the relative humidity data.

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Table 1. Monthly mean relative humidity in 2002, 2003, 2004 and 2008

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RH(%)	2002	2003	2004	2008
Jan	75	71	73	75
Feb	77	82	79	72
Mar	81	82	80	76
Apr	82	83	83	85
May	81	81	82	83
Jun	80	81	78	88
Jul	82	76	82	82
Aug	81	81	82	79
Sep	80	81	77	75
Oct	77	71	64	77
Nov	72	75	73	65
Dec	80	65	70	63

Please also note the Supplement to this comment.

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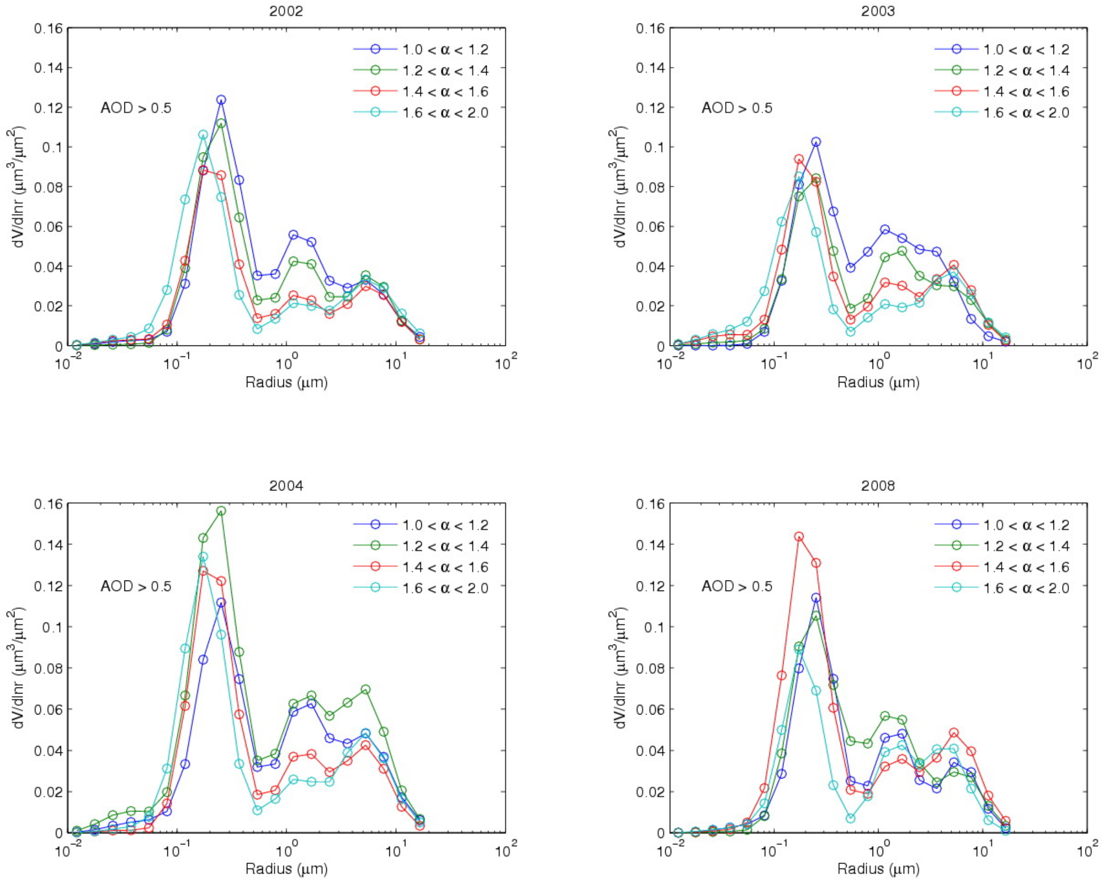

Fig. 1. Aerosol variation from July to September in the four years.

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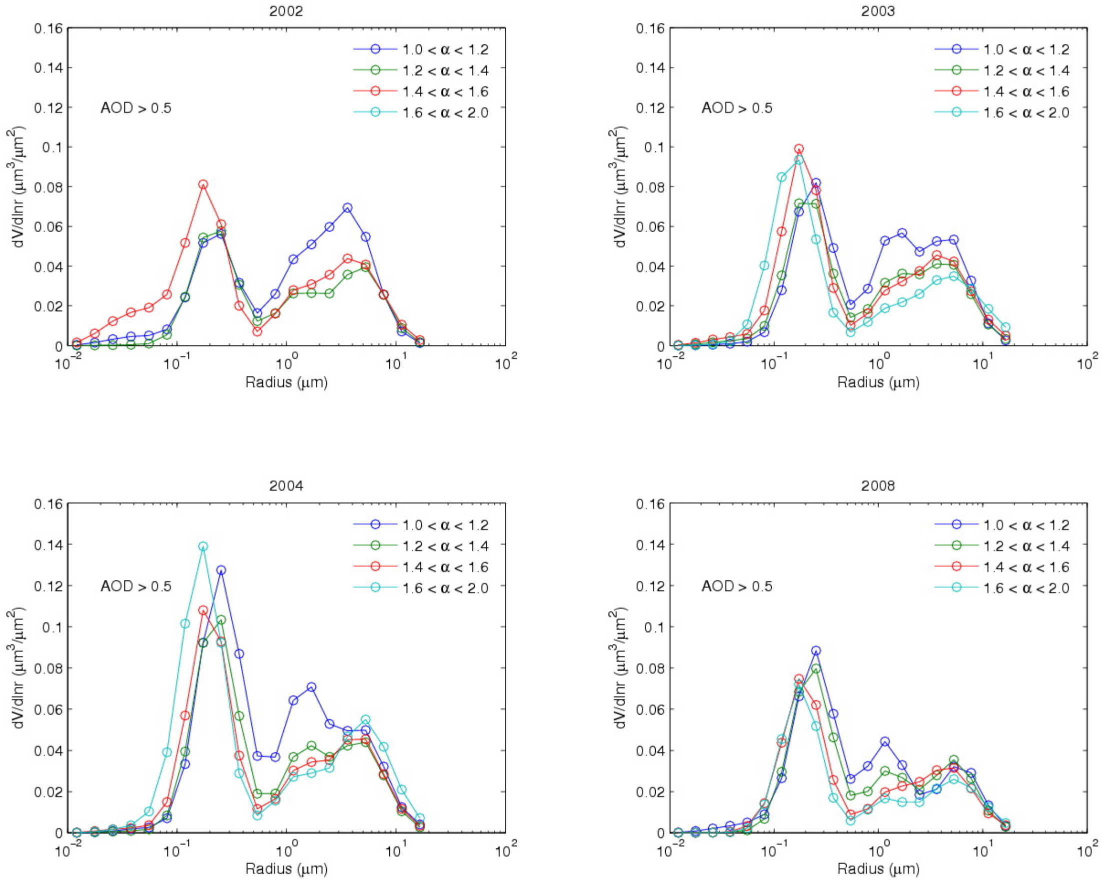

Fig. 2. Aerosol variation from October to November in the four years.

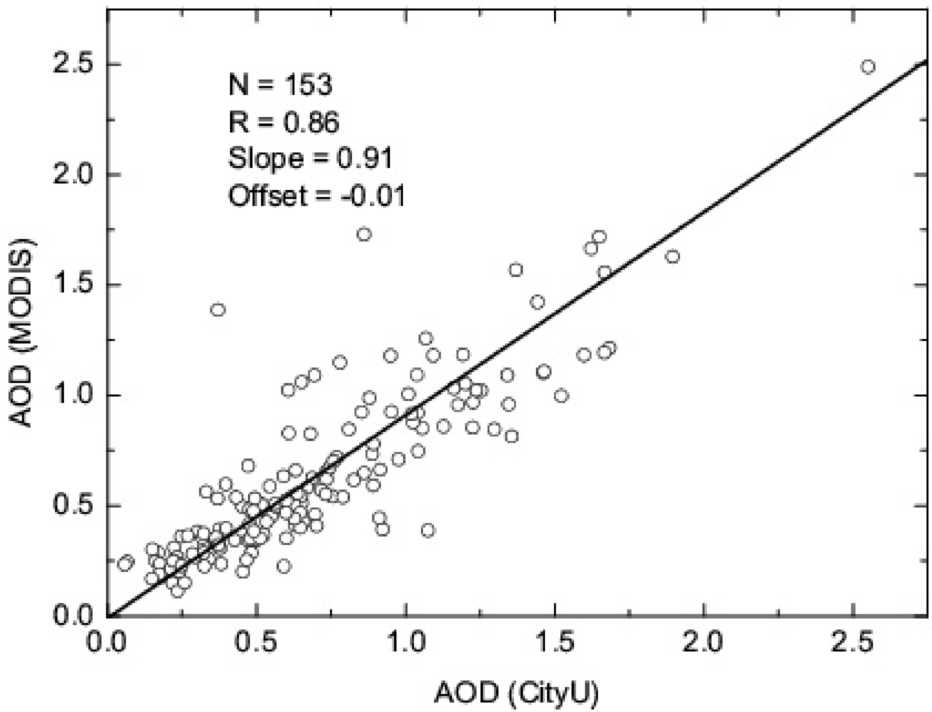

Fig. 3. Previous plot: MODIS mean-pixel AOD versus sun-sky radiometer daily mean AOD.

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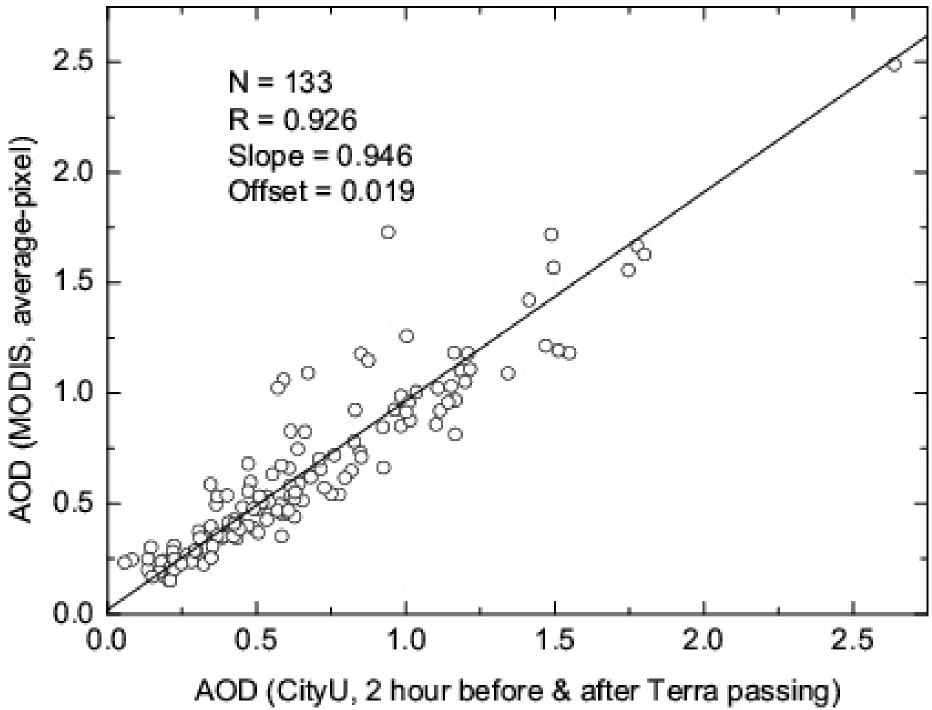

Fig. 4. MODIS mean-pixel AOD versus sun-sky radiometer mean AOD 2-hour before and after Terra passing.

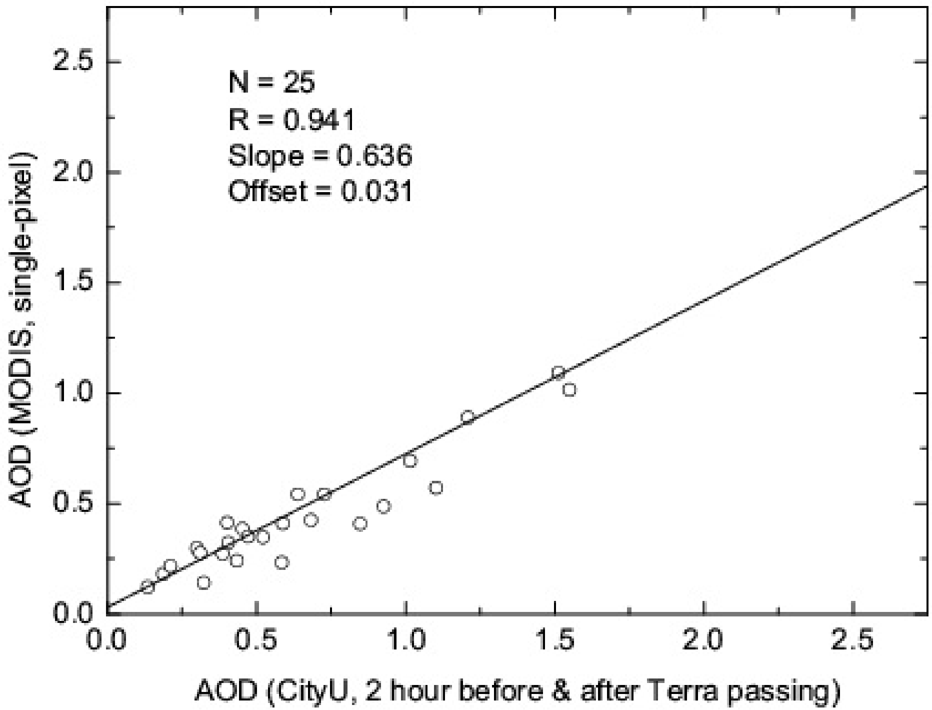

Fig. 5. MODIS single-pixel AOD versus sun-sky radiometer mean AOD 2-hour before and after Terra passing.

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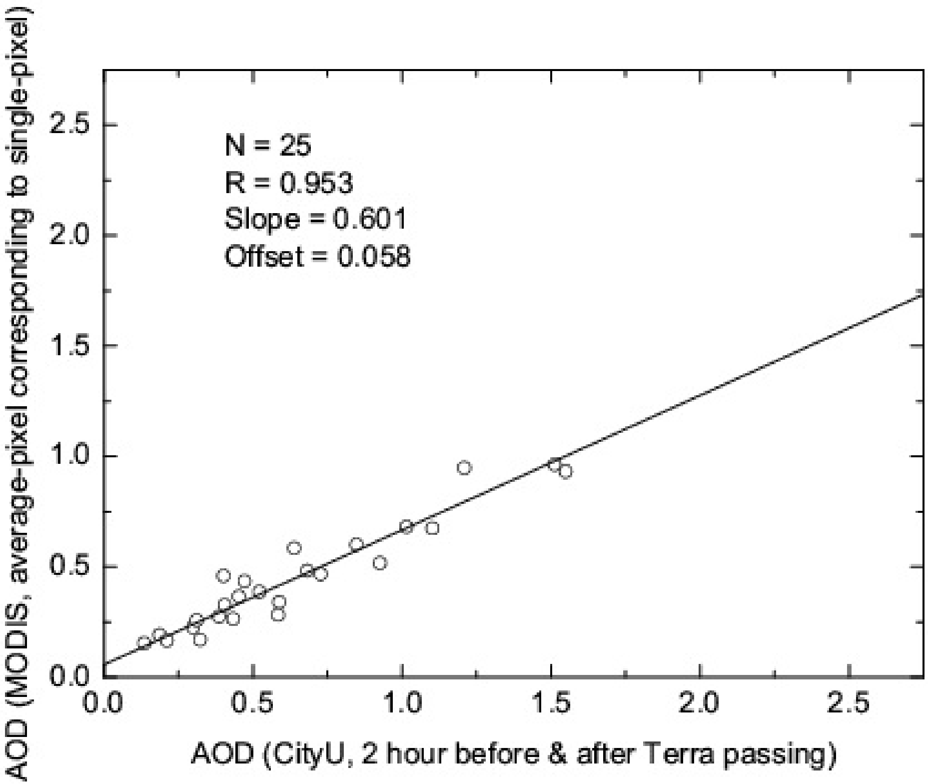

Fig. 6. MODIS mean-pixel AOD corresponding to the single-pixel data at the same day as in Figure 5 versus sun-sky radiometer mean AOD 2-hour before and after Terra passing.

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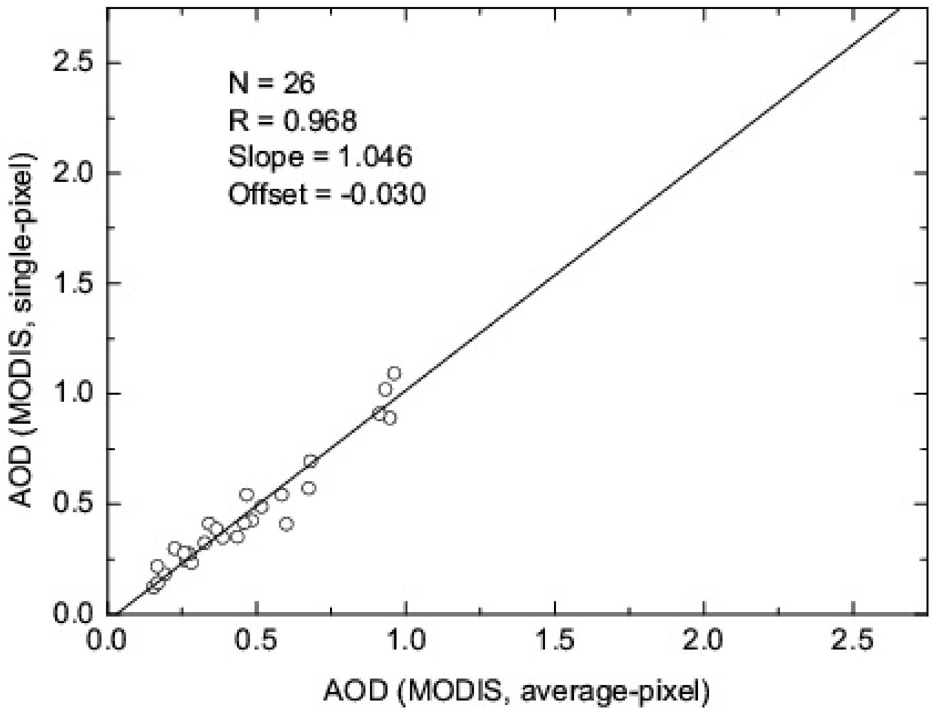

Fig. 7. MODIS mean-pixel AOD versus MODIS single-pixel AOD from July to November in 2002, 2003, 2004 and 2008.

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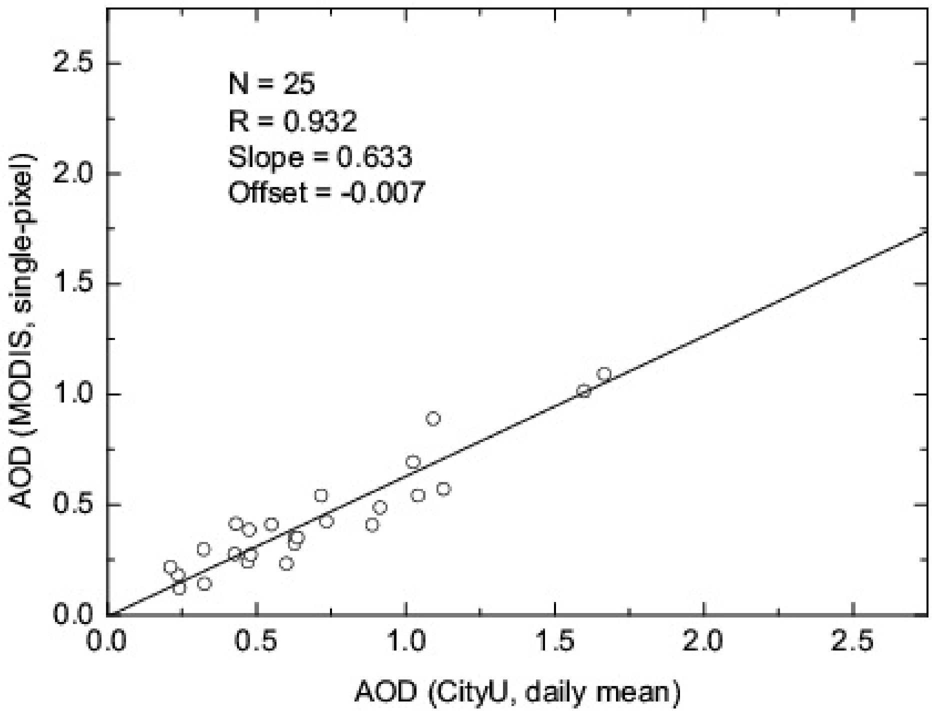

Fig. 8. MODIS single-pixel AOD versus sun-sky radiometer daily mean AOD.

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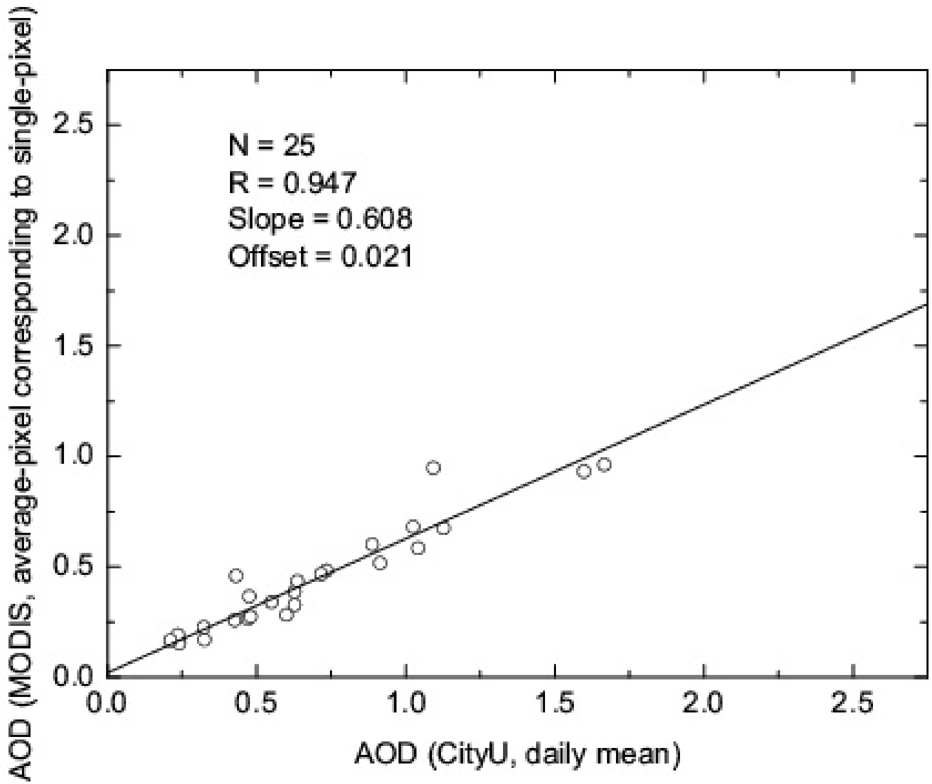

Fig. 9. MODIS mean-pixel AOD corresponding to the single-pixel data at the same day as in Figure 8 versus sun-sky radiometer daily mean AOD.

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