Supplementary material 8—Factors influence Relationships between PM_{10} and AOD/AOT

The possible factors that could cause differences between the surface PM_{10} concentration and the integrated columnar AOD/AOT are summarized as following:

(1) *AOD (or AOT) reflects the integrated optical properties of the columnar atmospheric aerosol, while the API-deduced PM_{10} concentration is a point measurement of ambient air pollution near the surface*. Difference in the atmospheric boundary layer (e.g. variations in the convection intensity and mixing layer height) will undoubtedly change the vertical distribution of aerosols and the fractional AOD of the surface layer in the total-column value, which can subsequently influence relationships between column AOD/AOT and surface PM_{10}.

Xia et al. (2006) described processes such as this in Beijing. That is, in summer, the aerosols can be transported to a high level of the atmosphere due to intense atmospheric convection result from heating of the atmosphere from below by strong solar radiation as well as from decrease in the frequency and intensity of atmosphere temperature inversion. This results in increase of the atmosphere capability and decrease of surface PM_{10} concentration; on the other hand, the column-integrated aerosol loading increases because more aerosols are emitted into the column and maintain their existence with relatively longer residence times. These processes result in higher AOT versus lower surface PM_{10} concentration in summer. While the processes in spring and winter were opposite. These authors found that AOT in summer is approximately two, three, and four times that in autumn, winter, and spring, respectively, for the same PM_{10} concentration, which supported their argument that more aerosols are aloft in summer as compared with other seasons (Xia et al., 2006).

(2) *Daily AOD/AOT and PM_{10} are obtained under different conditions*—daily PM_{10} concentrations include measurements under all-sky conditions and throughout the whole day, but daily AOD/AOT is available only in the daytime and under clear-sky conditions (Xia et al., 2006). MODIS AOD product is especially limited in

temporal coverage—observations were limited to the satellite overpass time.

(3) *It is the fine particles (e.g. PM_1, $PM_{2.5}$) rather than PM_{10} that plays the more important role in determining the aerosol optical properties and subsequently AOD/AOT as well as effects on visibility*. This based firstly on size of the fine particles is closer to the wavelengths of visible light and secondly on the fine particles mainly consist of anthropogenic emission materials (such as BC) with higher mass extinction efficiency compared with the natural origin material such as mineral dust. The aerosol particles with diameters of 0.6 – 1.5 μm have the strongest impact on atmospheric extinction at the wavelengths of visible light (Bullrich, 1964). Similarly, a study in Beijing showed that the submicron aerosol was responsible for ~80% of the light scattering at 530 nm during June 1999, even though it only contributed ~20% of the aerosol mass (Bergin et al., 2001); Song et al. (2003) also found a stronger relationship between the fine particle ($PM_{2.5}$) mass concentration and visibility degradation than the coarse particle in Beijing during 1999 – 2000. A study in Guangzhou also indicated that aerosol particles < 1 μm in radius have the largest contribution (about 70%) to the reduction of visibility (Deng et al., 2008a). As AOT is made up of mostly fine particles, Xia et al. (2006) indicated that PM_{10} is not the optimal indicator of AOT. Song et al. (2009) also concluded that AOD obtained from a visible channel is more sensitive to the mass concentration of $PM_{2.5}$ rather than that of PM_{10}.

(4) *While PM_{10} concentration is a simple measure of the total aerosol mass regardless of the size distribution and chemical composition, AOD/AOT is strongly influenced by the size distribution as well as the proportions of different aerosol components as these affect the aerosols' mass extinction efficiency, in addition to the same factors that govern the aerosol loadings*. As size distribution and chemical composition of aerosols can differ largely over various regions, this cause regional discrepancy in the relationships between AOD and PM_{10} (Song et al., 2009). Typically, mineral dust (mostly in coarse-mode) dominates in the arid region over northwestern China, while anthropogenic fine-mode aerosols such as carbonaceous and secondary species (sulfate, nitrate, and ammonium) are major contributors to PM

mass in other regions such as central-eastern China, NCP, SCB, and the coastal areas including SDP, YRD and PRD which were intensively influenced by human activity (Ye et al., 2003; Chan and Yao, 2008). This regional contrast in the size distribution and chemical composition is significant in the relationship between AOD/AOT and PM_{10}.

More to the point, several factors including mass extinction efficiency, hygroscopic growth factor (as a function of RH), and effective scale height (mainly determined by the vertical distribution of aerosols) also affect the correlation between satellite-derived AOT and PM mass (Wang and Christopher, 2003). Li et at. (2005a) compared MODIS AOD with API in Beijing during August 2000 to December 2003, and they found that the direct correlation between them was relatively low; but this correlation improved significantly after taking account of the seasonal variation of scale height and the vertical distribution of aerosols as well as considering the influence of RH. van Donkelaar et al. (2006) investigated the relationship between AOD and surface $PM_{2.5}$ concentrations in Canada and US for 2000 – 2001, they found that the relative vertical profile of aerosol extinction is the most important factor affecting the spatial relationship between satellite and surface measurements of $PM_{2.5}$, while temporal variation in AOD is the most influential parameter affecting the temporal relationship between the satellite and surface measurements.

Based on discussions above, we know that variations in the atmospheric boundary layer (convection intensity and mixing layer height), in aerosol size distribution and chemical composition, in source regions as well as transport pattern, in wet scavenging efficiency (due to precipitation and its frequency), could result in difference in the seasonal variations and regional discrepancy of AOD/AOT and surface aerosol concentration, thus influence their relationship.

For example, Xia et al. (2006) found that AOT at Beijing increases from January to June and then decreases gradually (inconsistent with PM_{10} concentration with higher values in winter and spring versus lower concentration in summer). This summertime maximum was also true for MODIS AOD (in contrast to low PM_{10} concentration) in North China and the northern part of East China as mentioned in

Song et al. (2009). In addition to the variation of atmospheric mixing layer height and aerosol vertical distribution as mentioned before, Xia et al. (2006) suggested that the effects of seasonal variation of aerosol sources and meteorological factors also play a role in the observed different seasonal changes in AOT and PM_{10}. Take Beijing for instance, the dominant airflow to the city is from northwestern regions where AOT is close to the background level in winter, in contrast to from southern regions where AOT is greater than 0.6 in summer (Xia et al., 2006); the advection of a high AOT pollution plume to Beijing in summer thus results in more aerosols aloft in summer than in winter.

Furthermore, Song et al. (2009) argued that the secondary aerosols, which are generally hygroscopic and easily transformed from precursor gases due to excessive photochemical processes, can grow with high humidity in the summer; this results in increase of the fine-mode particle size and the mass extinction efficiency (Chin et al., 2002); the higher mass extinction efficiency and the higher mass concentrations of fine-mode aerosols can therefore lead to higher AOD in summer. On the other hand, secondary aerosols transformed by the anthropogenic emission can exert a significant influence on the $PM_{2.5}$ mass concentration rather on the $PM_{2.5-10}$ concentration (2.5 μm ≤ diameter ≤ 10 μm). This is why PM_{10} mass concentration in the summer does not increase with the enhancement of MODIS AOD during the same period even in the highly populated and industrial areas.

For Northwest China, AOD varied in a similar manner except for that high AOD occurred earlier—April, May and June (Song et al., 2009), this probably reflects influence from the dominant mineral dust aerosol in that region during later spring to early summer. While for the southern part of Central-South China and the southern part of East China as mentioned in Song et al. (2009), AOD showed maximum values in spring rather than summer, which was attributed to frequent rainfall due to summer monsoon and wind pattern mainly from the southeastern ocean where the air is clean; to the contrary, the relatively dry weather and a dominant wind from the north with heavy anthropogenic pollution also contributing to the maximum value in spring. Li et al. (2005b) also found similar pattern of AOD with minimum in July and maximum in

March over Urumchi, but the springtime high AOD was attributed to the "accumulative effect" of air pollution due to heavy wintertime emissions from coal combustion for domestic heating as well as scarce precipitation in winter. Furthmore, Urumchi located on the northern piedmont of Tianshan Mountains, with mountains around to the east, south and west and subdued alluvion plain to the north, this unique basin terrain leads to difficulty for air pollutants outflow and diffusion. One may refer to these references for more details about seasonal variation of AOD/AOT in relationship with surface PM_{10} concentration over China.

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