

Impact of aerosols on radiation during a heavy haze event in Beijing

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Abstract. In order to understand the influence of anthropogenic aerosols on radiation in the urban boundary layer, we measured atmospheric aerosol mass concentrations (PM_{10} and $PM_{2.5}$), integrated solar radiation, wind and temperature at different layers of a 325-m iron tower. A typical heavy haze process occurring during the period of October 2004 was analyzed. It is observed that the inversion layer and the weak wind was the most important factor causing the accumulation of pollutants. The results show that the PM_{10} concentrations under polluted day conditions is about 84 times ($537.1\mu g m^{-3}$) higher than those on clear weather conditions ($6.4\mu g m^{-3}$). The difference in the solar radiation between 2m and 280m became smaller ($93.07 W m^{-2}$ to $16.07 W m^{-2}$) when pollution turned heavy, while the attenuations rate changed large (16.76% to 20.96%)

1. Introduction

The influence of aerosols on climate change has become a very important topic during the past decade^[1]. Aerosol particles are known to cool or warm the atmosphere directly by absorption, scattering, and emission of solar and terrestrial radiation and indirectly by changing the albedo and the life time of clouds by acting as cloud condensation nuclei^[2]. Researches on aerosol properties and radiative effects at the surface were performed in northern China^[3-7]. Xia et al were also concerned with aerosol radiative effects.

Atmospheric pollution in Beijing has been a significant problem for more than a decade, due to the unrestricted growth of population and vehicles. To analyze the character of boundary layer in heavy polluted Beijing city, the experiment was carried out during a typical period from fall with clear sky and better air quality to winter with more heavy pollution, especially within the heating period. The period ran continuously from 16th October to 20th December 2004. The measurement was made at IAP/CAS in the northwest part of Beijing (39°58'N, 116°22'E) between the 3rd and 4th ring roads of the city.

In the present study the impact of aerosols on boundary layer radiation change were shown, and the attenuations radiation of two layers was shown for this typical urban pollution process from a clear day to a heavy haze day.

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2. Instrumentation and site description

Measurements were carried out on a 325m iron tower, which is located in the Institute of Atmospheric Physics (IAP)/CAS (Chinese Academy of Sciences). The apparatus were placed on the iron tower at two different heights 2m and 280m. At each height downward and upward solar irradiances, were separately measured with upward-facing and downward-facing Epply pyranometers (PSP). The short-wave radiation downward and the short-wave radiation upward denoted as SWD and SWU respectively. The temperature and wind were also observed at fifteen layers of the 325m iron tower. Those meteorological data were obtained from the automated weather station, Milos-520, made by Vaisala Company, Finland. The concentration of PM_{10} and $PM_{2.5}$ were monitored with a TEOM (tapered element oscillating microbalance, R&P 1400, Rupprecht and Patashnik, Inc.). The apparatus were placed at the iron tower and the accuracy of measurements was $\pm 1.5 \mu g/m^3$ for per hour.

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3. Results and discussion

3.1. The analysis of pollution and weather background

Figure 1 shows variations of air pollution index (API) and PM_{10} of daily average concentration from 12th October to 12th November 2004 in Beijing (<http://www.sepa.gov.cn/quality/air.php3>). The time frame was chosen because it contained a typical polluted process, which was from a clear day to a heavy haze day. It was found that the pollution has a quasi-periodic change with a periodic time of approximately five to six days. The heaviest polluted process occurred from 26th October with API of 34, to 30th October with API of 219. PM_{10} daily average concentration increased from only $39.1 \mu g/m^3$ on 26th October to $332.5 \mu g/m^3$ on 30th October correspondingly.

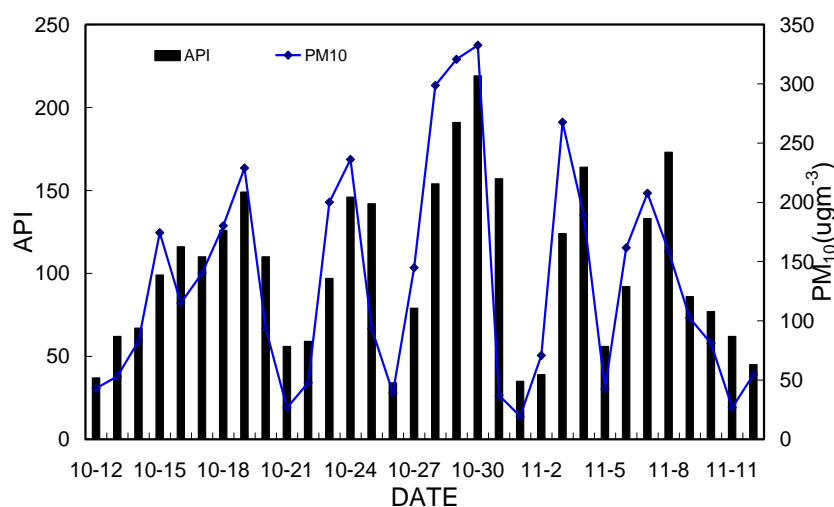


Figure1. Variation of API and daily average concentration of PM_{10} in Beijing from 12th October to 12th November 2004

The boundary layer meteorological conditions during this polluted process are presented in Figure 2. **Figure 2(a)** demonstrates of vertical outline change of temperatures at 5 o'clock AM from 26th to 30th October. It was observed that the inversion layer was more strengthened on 26th October at 05 o'clock. The inversion layer was gradually strengthened till 27th October. There were two inversion layers at the 320m down below. These inversion layers held up the aerosols diffuse. As far as the diffusion of pollutants, particularly in the perpendicular direction which is concerned, the existence of inversion layer played a very effective role in repressing the diffusion. So aerosol pollution became heavier and heavier. (**Figure 2(a)**).

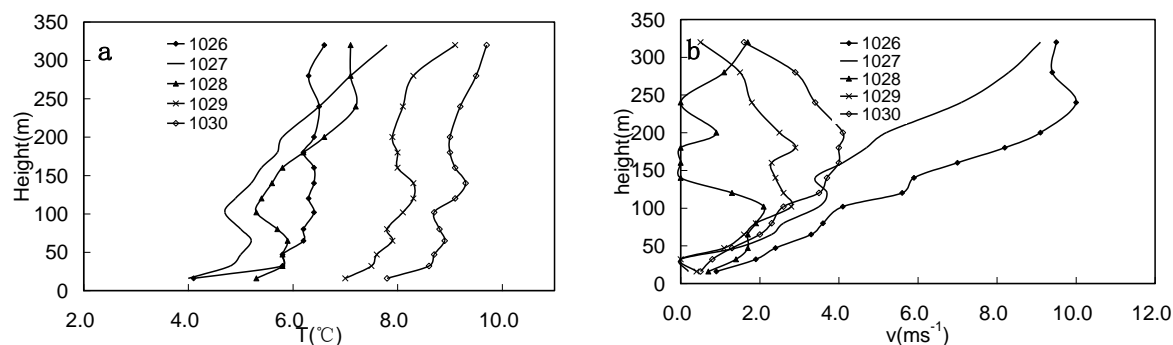


Figure 2. Variation of temperature at 05 o'clock (a) and wind (b) at 21 o'clock Beijing Time on vertical direction from 26th October to 30th October. (Note: The different lines indicated different date.)

Besides the inversion effect mentioned above, weak wind was also an important reason of this polluted process. It could find from **Figure 2(b)** that from 26th to 27th October, velocity at 9 o'clock PM upgraded with the elevation of height. From 28th October, velocity began to drop down with the change of height and became chaotic and irregular. Several layer's velocity was 0.0ms^{-1} the velocity at the layer close to the ground almost became wind shadow. The pile-up of pollutants was possibly supplied with advantageous circumstance and the polluted situation was further degenerated. At beginning the aerosols could get so heavy polluted with these two meteorological conditions

3.2. Timely variation of PM data

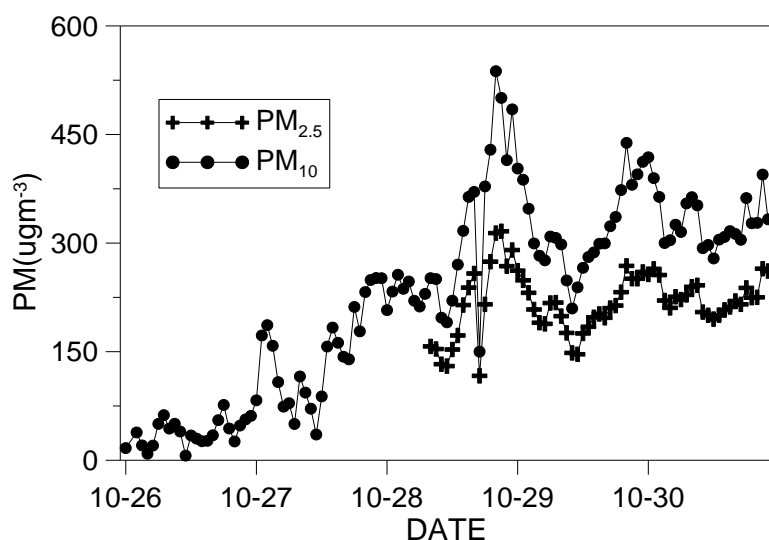


Figure 3. Variation of PM_{2.5} and PM₁₀ from 26th October to 30th October at 8m

Figure 3 shows the variations of PM_{2.5} and PM₁₀ at altitudes of 8m of the tower during this polluted episode. The discrepancy of PM₁₀ and PM_{2.5} varied not apparently in the polluted day. On 26th October is a clear day the minimum value PM₁₀ only $6.4\mu\text{g}\text{m}^{-3}$. From clear day to polluted day the PM increased, the PM₁₀ and the PM_{2.5} can get $537.1\mu\text{g}\text{m}^{-3}$ and $313.2\mu\text{g}\text{m}^{-3}$ on 29th respectively. The PM₁₀ concentrations under polluted day conditions is about 84 times higher than those on clear weather conditions

3.3. The solar radiation at the two layers

Figure 4 shows the variations in the solar observed at altitudes of 2m and 280m of the tower during this typical polluted episode. The discrepancy of short-wave radiation in these two altitudes varied apparently in the clear day. On 26th October the difference in SWD between the 2m and 280m heights was 100Wm^{-2} at noon. From a relative clear day to polluted days the radiation flux changed greatly, with decreases in SWD, SWU. The SWD radiation at noontime at 280m height changed from 554Wm^{-2} to 208Wm^{-2} . The difference in the solar radiation between the two layers became smaller when pollution turned heavy.

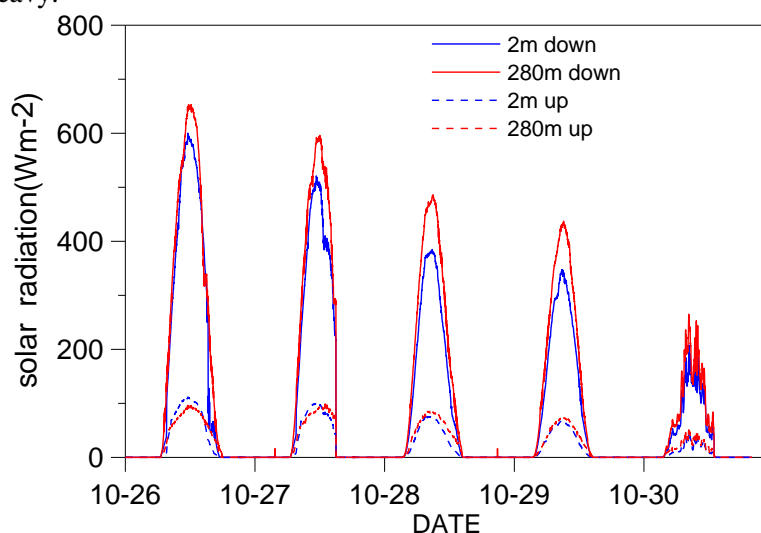


Figure 4. Variation of short-wave radiation from 26th October to 30th October at 2m and 280m height

Table 1 shows the difference of global radiation at 12:00 between the two layers. It shows that the global radiation attenuations of two layers changed from 93.07Wm^{-2} to 16.07Wm^{-2} in this episode. While the global radiation attenuations rate increased from clearly day to haze day, the atmosphere got very gray at 280m and 2m and the corresponding daily average PM_{10} concentration.

Table 1. Comparison of solar radiation on 280m and 2m

DATE	280m (Wm^{-2})	2net (Wm^{-2})	The attenuations (Wm^{-2})	The attenuations rate (%)	PM_{10} (μgm^{-3})
10-26	555.31	462.24	93.07	16.76	39.09
10-27	504.42	407.03	97.39	19.31	144.76
10-28	400.37	306.02	94.35	23.56	307.65
10-29	357.52	279.18	78.34	21.91	312.4
10-30	75.67	59.6	16.07	20.96	332.54

4. Conclusions

We measured two layer's (8m and 240m) radiative flux, different layer's aerosols mass concentration and meteorological factors in Beijing during a heavy polluted period time. The impact of aerosols on radiation at different heights of the boundary layer was analyzed in this typical urban pollution process. The PM_{10} concentrations under polluted day conditions is about 84 times ($537.1\mu\text{gm}^{-3}$) higher than those on clear weather conditions ($6.4\mu\text{gm}^{-3}$). Daily-averaged PM_{10} concentration increased from $39.1\mu\text{gm}^{-3}$ to $332.5\mu\text{gm}^{-3}$ over this period. The discrepancy of short-wave radiation in different layers was observed to vary apparently in Beijing in winter for clear days. The discrepancy of SWD at two

layers can arrive at 100 Wm^{-2} at midday for clear days. The SWD radiation at noontime at 280m changed from 554 Wm^{-2} to 208 Wm^{-2} from a clear day to a heavy polluted day.

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