The Daily Evolution of Black Carbon Profiles over Shanghai during Winter

Juan Li*, Qingyan Fu, Dongfang Wang, Juntao Huo, Yihua Zhang, Qinggen Bian, Jun Pan

Shanghai Environmental Monitoring Center, Shanghai, China, 200235

Wen Yang and Liang Xian

Chinese Research Academy of Environmental Sciences, Beijing, China, 100012

1. INTRODUCTION

For China, this was the first vertical observation of multi-pollutants within a 1000 m atmospheric boundary layer over a metropolitan area using a tethered balloon filled with 1600 m^3 Helium. The pressing demand in China to improve air quality (Huang, et al, 2014) brought about this new approach. Ultimately this experiment did not only stir up our appreciation of observational technology, but also it had a profound significance on our deeper understanding of the causes of heavy air pollution, its various transport patterns (Trompetter, et al., 2013), and on improving the performance and forecast accuracy of air quality models (M. Lothon,et al., 2014).

2. FIELD MEASUREMENT

The field (N30°49'47", E121°30'04") was located in southern Shanghai, which borders the East China Sea. The surrounding area was by the campuses of a couple of universities. The chemical industrial park is around 10 km southwest from this field.

The platform was designed for vertical distribution and consisted of two components. One was the tethered balloon filled with 1600 m^3 Helium; the other component was an on-line monitoring instrument assembly. The tethered balloon not only brought a rack containing all of instruments to ascend and descend, but also provided electricity and telecommunication through the tethered line. The design of the balloon allowed a maximum load of 200 kg. Monitoring instruments were deployed to detect black carbon (BC), NO_x , O_3, SO_2, particulate concentration, number concentration of particulate, size distribution of aerosol, along with meteorological variables like temperature, relative humidity, and wind. BC (Model: AE-31, 880 nm) was a target pollutant for us to record its daily evolution in a vertical profile because of its inertness. After quality control and 1-h preheat of all of monitoring instruments, the platform was launched to ascend at a rate of 0.5m/s above 150 m ground through 1000 m. It was defined as one vertical profile of BC. The balloon remained for 5 min at the altitude of 1000 m, the platform then descended at the same rate. It was seen as the other profile. The favorable weather condition for the vertical distribution is ground winds lower than 5 m/s without obvious precipitation.

To better understand the daily evolution of BC profile, the mixing layer height and wind profile were also probed synchronously on the field spot with ceilometer (Vaisala, Model: C31) and Lidar (Windube 70), respectively. The diurnal variation of wind and mixing layer height were presented in Figure 1 and 2. Meanwhile, the ground monitoring vehicle was set to collect the in-situ data, too.

3. RESULTS AND DISCUSSION

On December 13, 2013, there were ten BC vertical profiles obtained to characterize the diurnal vertical profiles on four typical times. That was, sunrise, noon, sunset, and midnight, for they were very critical times to discover the cause of air pollution and the path of transport.

At the beginning and end of sunset, the turbulence in atmospheric boundary layer over land became active (Figure 3). BC concentrations on the ground, near the ground, and at the altitude of 1000m were in the range of 15323-18034 ng/m^3, 6100-14686 ng/m^3, and 1608-3991ng/m^3,

**Corresponding author:* Juan Li, Shanghai Environmental Monitoring Center, No. 55 Sanjiang Rd.; Shanghai, China, e-mail: juanliut@gmail.com.

respectively. Generally, BC concentrations decreased with the height. One could see that at sunrise the BC concentrations at the same altitude gradually became lower. It was likely that the mixing layer height increased as the BC concentrations were diluted. Also, the fluctuation of BC profiles rose rapidly, suggesting that BC was subject to transport ups and downs with the turbulence.

Around noon, BC concentrations tended to be constant at all levels (Figure 4). LST15:00 profile BC concentrations versus the height had no big variance; its distribution was in the range of 3194-3862 ng/m^3. Approaching noon the BC concentrations near the ground dropped to 3862-4180ng/m^3 compared with those measured at sunrise. In the upper layer, the BC slightly decreased from 5310 to 3469ng/m^3 over time, indicating that turbulence entrained pollutants like BC to move upward and downward. As a result, BC was distributed evenly with the height of the balloon.

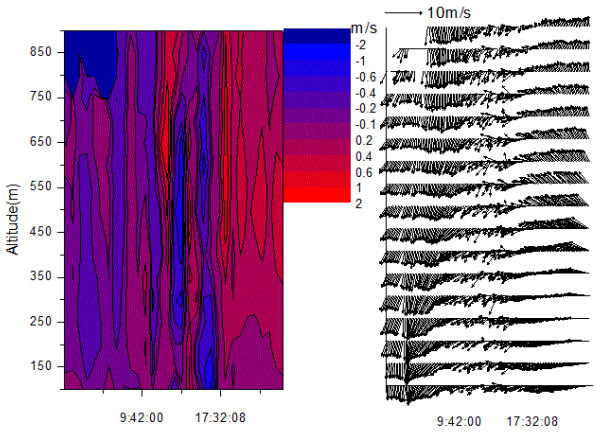
Around sunset, BC concentrations near the ground continuously decreased to 1234 ng/m^3, while at the upper layer, i. e. at the altitude of 1000m, BC concentrations were persistent up to 4000 ng/m^3 (Figure 5). With the coming of night rush hour, BC near the ground showed an increase.

At midnight, the difference of BC profile both near the ground and at the upper layer remained quite slight (Figure 6). It was worth noting that there was an abrupt change in the range of 600 m and 800m. This was likely linked to the atmospheric stratification formed at night.

The understanding of the evolution of BC in the atmospheric boundary layer would be very helpful in forecasting and warning of air quality over cities.

These results demonstrated pollutant BC was not only transported from the surface to the upper air, but also be transported downward. It would be very useful to quantitatively evaluate the contribution of vertical transport of pollutants in air pollution episodes at regional level.

4. FIGURES and TABLES



(a) Vertical wind (b) Horizontal wind

Figure 1: Wind variation with the altitude on Dec. 13, 2013

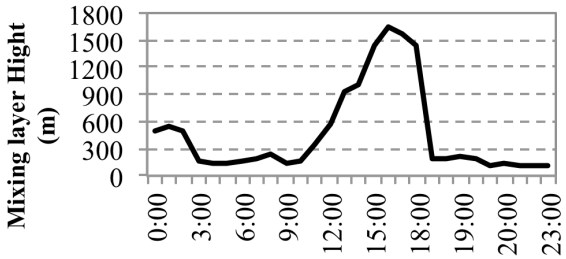


Figure 2: Daily variation of mixing layer height on Dec. 13, 2013

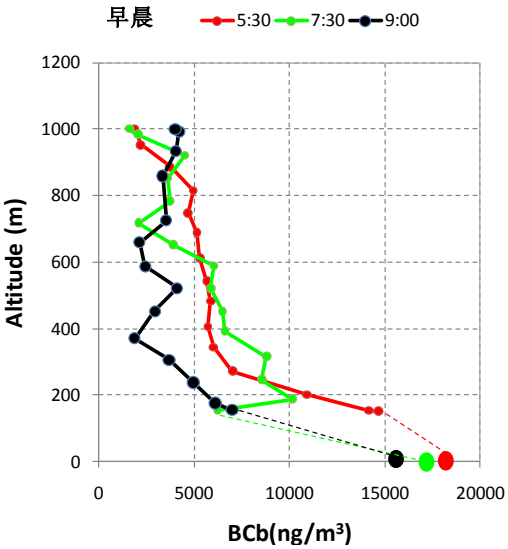


Figure 3: BC profiles at sunrise

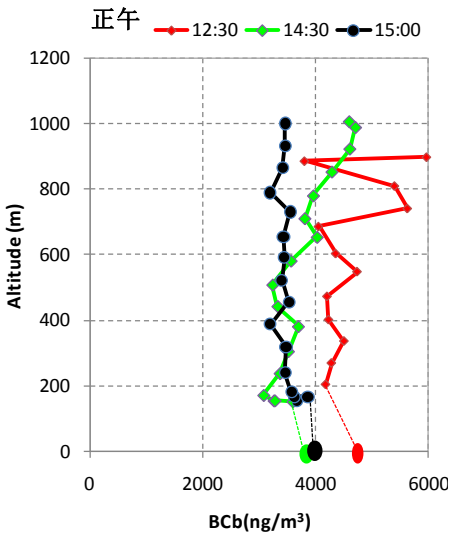


Figure 4: BC profiles at noon

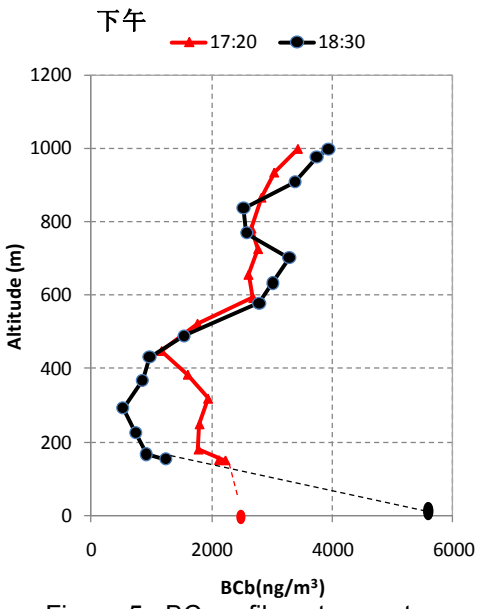


Figure 5: BC profiles at sunset

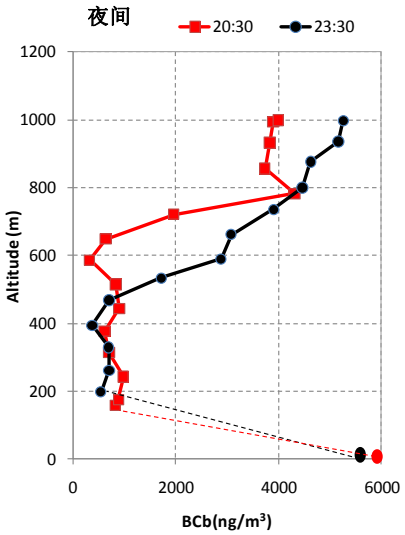


Figure 6: BC profiles at midnight

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