Rapid formation of intense haze episode in Beijing

Yonghong Wang\textsuperscript{1,2}, Yuesi Wang\textsuperscript{1,5}, Guiqian Tang\textsuperscript{1}, Tao Song\textsuperscript{1}, Putian Zhou\textsuperscript{2}, Zirui Liu\textsuperscript{1}, Bo Hu\textsuperscript{1}, Dongsheng Ji\textsuperscript{1}, Lili Wang\textsuperscript{1}, Xiaowan Zhu\textsuperscript{1}, Chao Yan\textsuperscript{2}, Mikael Ehn\textsuperscript{2}, Wenkang Gao\textsuperscript{1}, Yuepeng Pan\textsuperscript{1}, Jinyuan Xin\textsuperscript{1}, Yang Sun\textsuperscript{1}, Veli-Matti Kerminen\textsuperscript{2}, Markku Kulmala\textsuperscript{2,3,4} and Tuukka Petäjä\textsuperscript{2,3,4}

\textsuperscript{1}State Key Laboratory of Atmospheric Boundary Layer Physics and Atmospheric Chemistry (LAPC), Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China

\textsuperscript{2}Institute for Atmospheric and Earth System Research / Physics, Faculty of Science, P.O.Box 64, 00014 University of Helsinki, Helsinki, Finland

\textsuperscript{3}Joint international research Laboratory of Atmospheric and Earth SysTem sciences (JirLATEST), Nanjing University, Nanjing, China

\textsuperscript{4}Aerosol and Haze Laboratory, Beijing Advanced Innovation Center for Soft Matter Science and Engineering, Beijing University of Chemical Technology (BUCT), Beijing, China

\textsuperscript{5}Centre for Excellence in Atmospheric Urban Environment, Institute of Urban Environment, Chinese Academy of Science, Xiamen, Fujian 361021, China

Corresponding authors: Yuesi Wang and Markku Kulmala
E-mail: wys@mail.iap.ac.cn; markku.kulmala@helsinki.fi

Submitted to: Atmospheric Chemistry and Physics
1. **Synoptic conditions during this intense haze episode**

Figure s1. Synoptic weather situation during the air pollution episode. Figures are produced from MICAPS software. The red five star represents the observation site. The meteorology conditions on the surface were characterized as high solar radiation and high ultraviolet radiation, which results in a warm temperature around 0-10 degree Celsius. The synoptic weather situation was characterised by a cold front during 16th and 17th of November in Mongolia so the surface wind speed is quite small and the wind direction is unregularly. (Figure S1). As shown in figure s5, the variation of mixing layer height can be explained mostly by variation of buoyancy flux carried out on 47m observation platform during this air
2. Characteristic of air pollutants vertical distribution in Beijing

Figure s2. Vertical distribution and correlation of PM$_{2.5}$, ozone and NOx in 8m, 120m and 280m Beijing meteorology tower during day time (10:00~17:00) with solar radiation values. The rainy hours were deleted.
3. Decreased solar radiation and increased PM$_{1-2.5}$ with decreased mixing layer height

Figure s3. (a) Vertical variation of direct radiation and UV radiation during a clean day and haze day. The direct radiation measurements were conducted at 8 m and 320 m height of the tower. The UV radiation measurements were carried out at 8 m, 140 m and 280 observation platforms, respectively. (b) Variation of PM$_1$ mass concentration and mass fraction of PM$_1$ in PM$_{2.5}$ with decreased mixing layer height (up figure) in winter, variation of net radiation and UV radiation during daytime in winter.
Figure s4. Statistics of variation of air pollutants at 8m, 120m and 280m with mixing layer height.

Figure s5. Variation of observed mixing layer height compared with calculated $Fb$ during the intense haze period.
Figure s5. The variation of NO\textsubscript{x} mixing ratios with variation of mixing layer height at 8m, 120 m and 280m observation platform. The concentration of NO\textsubscript{x} was divided into each bins according to corresponded PM\textsubscript{2.5} concentrations. The solid points represent NO\textsubscript{x} concentrations as the corresponded PM\textsubscript{2.5} concentrations large than 75 ug m\textsuperscript{-3} under a fixed mixing layer height. The grey points represent mean values; the red line represents medium values. The shadow area corresponding to increased amount of NO\textsubscript{x} with decreased mixing layer height.

4.Increase of secondary aerosol formation with decreased mixing layer height

Figure s6. Chemical composition of organic, nitrate, sulfate, ammonium and
chloride with decreased level of mixing layer height. The mass fraction of each composition with variation of mixing layer height are also presented. The mass fraction of nitrate, sulphate and ammonium increased, as mixing layer height decreased from over 1400m to 1000~1200m. However, the mass fraction of organic also increased with decreased mixing layer height from 1000m to less. The data was selected during daytime (10:00~17:00).

Figure s7. Diurnal variation of solar radiation, mixing layer height observed at 8 m observation platform, volume mixing ratio of NOx, mass concentration of PM2.5 and volume mixing ratio of ozone simultaneous measured at 8 m, 120 m and 280 m observation platform at Beijing 325 m meteorology tower.