3.3 AN OBSERVATIONAL ANALYSIS OF VERTICAL DISTRIBUTIONS OF SO_2 IN THE SURFACE LAYER OF BEIJING DURING COLD WAVE PASSING IN WINTER

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1. Introduction

At present, the conventional monitoring networks of urban air quality cannot provide us with sufficient information to acquire the spatial and temporal changes of air quality, especially rules of their vertical distributions, which are obviously essential to comprehensively understand the air pollution features. Additionally, our understanding of the rule of surface layer in urban area is, undoubtedly, significant to improve living conditions of high-storied buildings as well as the city planning and urban air quality model. In combination with the conventional atmosphere data from Beijing 325-meter meteorological tower, we conducted simultaneously continuous observations of SO_2 concentration at the height of 15m, 50m, and 80m, respectively. The data are analyzed to understand the influence of changes of wind and temperature within urban boundary layer on the vertical distribution of SO_2 in the surface layer.

2. Observation

Using Beijing 325-m meteorological tower and 28-Storied Foreign Expert Building around JiangXiang Bridge that is on the fourth ring road, we made a gradient observation of the low-height SO_2 concentration and meteorology field continuously and simultaneously from 25 January to 3 February 2000. We set 15 observation platforms with the logarithm space between each other on the tower. Each layer provided a continuous observation of wind velocity, wind direction, temperature and humidity. We respectively deployed an SO_2 analyzer on the second (15m), eighteenth (50m) and twenty-eighth floor (80m) to make continuous observations of SO_2 concentrations.

The instrument on the second floor (15m) is 43S-type pulse fluorescent method SO_2 analyzer made by American Thermoelectric Inc. On the 18^{th} and 28^{th}, there are 8850 fluorescent SO_2 analyzers made by American Monitor Labs.

3. The Weather during Observation

In the vertical gradient observation of SO_2, we caught a full process of outbreak of cold wave. From the 850 hPa weather map on 22 January (not shown), a strong cold air moved southward along the 115^0 E meridian, and the northwest-southeast cold trough just moved out of Beijing. Beijing lied near the edge of frontal zone of cold front. On 25 January, the cold frontal zone had controlled southern China. Beijing lied within the cold frontal zone. Temperature in Beijing was decreased by 10°C due to frontal surface passing. On 30^{th} the

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center of cold frontal zone lied about 400 km north of Beijing.

4. Relationship between the structure of boundary layer and SO_2 vertical distribution

During the two processes of cold air outbreak, including from 25th to 27th January and from 28th January to 1st February, there existed a zone of maximum wind velocity at 280 m, with an external velocity reaching 12-15 m/s in the center of the field. Generally, it was five to six times higher than the surface wind velocity of 2-3 m s. Moreover, the whole layer had a great wind shear. The surface temperature increased as the sun rose, and then the great wind field in the upper layer disappeared. According to the spatial-temporal distribution of temperature, there was an obviously downward cold tongue during the cold air outbreak. Along with the center of great wind field, there often existed a thin inversion layer at about 280 m. Before the sunrise, the lapse rate of temperature was very small in the near-surface layer, with no surface inversion.

In general, the results of observed SO_2 show that along with the appearance of great wind in upper layer, the difference of SO2 concentration between the upper and lower layer was decreased, and the SO_2 concentration was also decreased. As the great wind center was weakened, SO_2 concentration in each layer began to rise. After the breakdown of the wind core, the SO_2 concentration rose sharply.

In order to further analyze influences of the spatial-temporal distribution of wind and temperature on the vertical distribution of SO_2, Figs. 1 and 2 show the six-day (27 January to 1 February) consecutive measurements of wind, temperature and SO_2 concentration, respectively.

We can see from Fig. 1 that the process of previous cold wave was over before 8 o'clock 27th, while the wind velocity in the great wind center decreased dramatically. With the breakdown of the core, wind velocity in whole boundary layer was small. A typical winter stable layer occurred at night. The 850 hPa weather map on 28th 20 o'clock showed that the second cold wave formed and approached Beijing. From 16 o'clock on 28th to the noon of 1st February, the wind velocity in each layer began to increase. Especially during night an center of maximum wind velocity (15m/s) was obviously formed, most of which appeared in the layers between 200m and 280m.The center of wind velocity maximum did not exist continuously but had periods varying from 1 to 4 hours, during which there was no inversion layer. Because of the composite function of thermodynamic turbulence, the maximum of wind velocity often disappeared after the sunrise, and increased at night.

Before 8 o'clock on 27th, because of the great wind shear formed by the previous cold wave, the concentration of SO_2 in each layer was low and distributed homogeneously. Along with the end of cold wave and the breakdown of the low-layer great wind center, the SO_2 concentration in each layer increased sharply. At 23 o'clock, a maximum was formed within each layer. The mixing ration of SO_2 in the 80 m layer reached 475 ppb (about 1.30 mg/m^3), and brought about a serious SO_2 pollution. During the course of the second cold wave, i.e. from January 29 to February 1st, whenever it was day or night, the concentration of SO_2 maintained a low level, which was normally lower than 150 ppb. The peak values of SO_2 in each layer varied consistently. During night, the concentration of each layer distributed evenly. During day, the concentration at 50 m and 80 m was slightly higher than that in surface layer. After the end of the second cold wave, the great wind core of low-layer broke down completely, while at the noon of February 1st, the concentration of SO_2 rose sharply, and arrived to be 300 ppb very soon. The maximal concentrations appeared to be in the 80m layer but not in the surface layer of conventional sampling. Fig. 2 clearly shows the above mentioned processes.

5. Conclusion

According to the Beijing 10-day vertical observation of the SO_2 concentration and the simultaneous analysis of meteorological observations based on Meteorological Tower, we can draw the following conclusions: (1) There were two times of outbreak of cold air during observation. The structure of boundary layer was affected during outbreaks of cold air accompanying with lower level wind maximum core (LLWMC), which has an important effect on the change of SO_2 concentration. When there existed LLWMC, the concentration of SO_2 was comparatively low and homogeneous vertically. After collapse of LLWXC, the concentration of SO2 decreased rapidly. (2) During the daytime, thermodynamic turbulence played an important role in the vertical distribution of SO_2 concentration, and the maximal concentration always maintained at the height of around 80 m. (3) During night, the condition of breeze and inversion was the main reason that caused pollution with high SO_2 concentrations in the surface layer.

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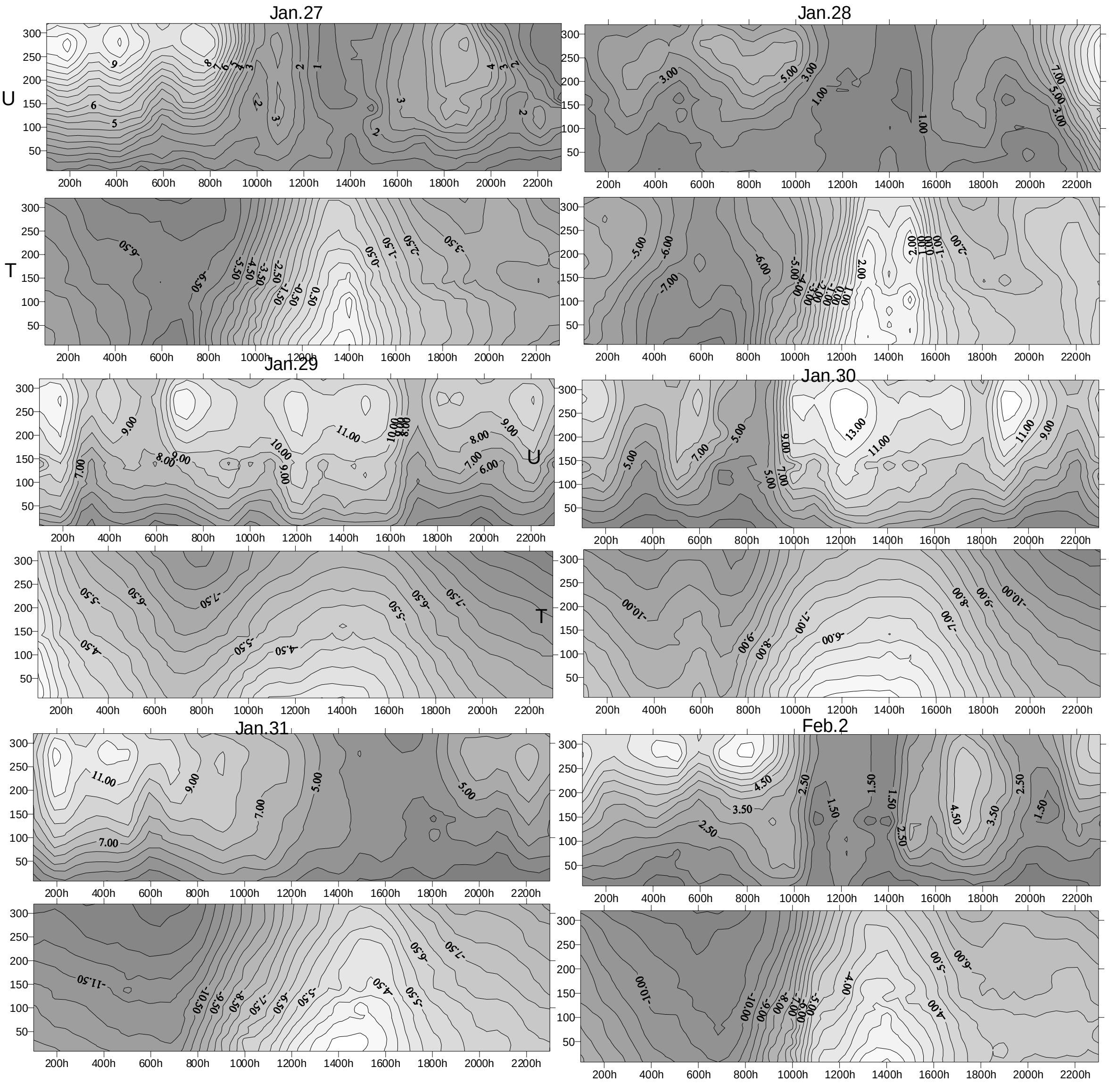

Fig. 1 The vertical distribution of wind and temperature from Jan.27th Feb.1st,2000

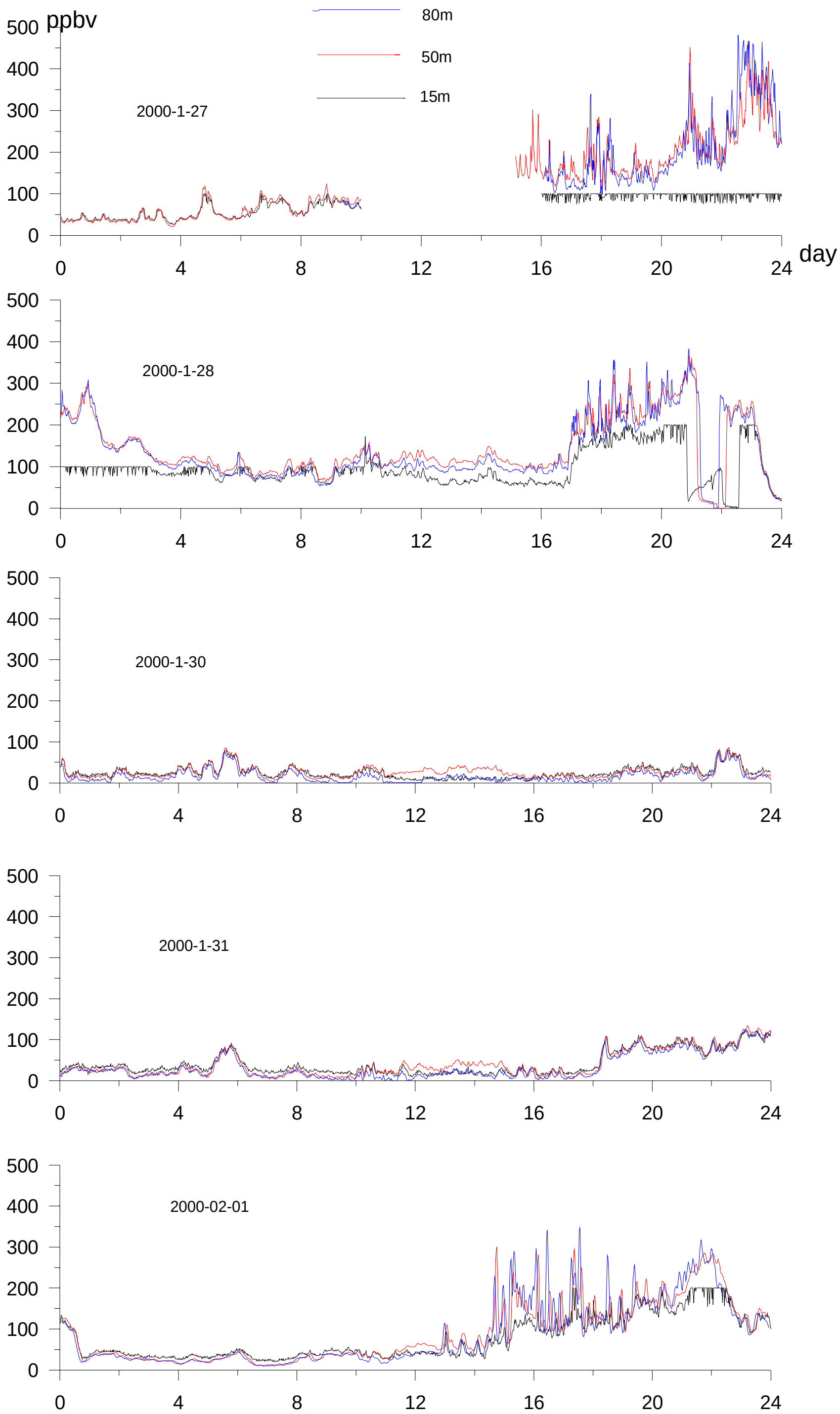

Fig. 2 The variations of SO_2 at different heights from Jan. 27th to Feb.1st 2000