SEVERE PARTICULATE POLLUTION IN LANZHOU CHINA

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ABSTRACT

Spatial and temporal variability of SO_2, NO_2, NO_x, PM_{10} and total suspended particles (TSP) concentrations in Lanzhou, China is analyzed using the observational data collected from October 1999 to April 2001. The concentrations of SO_2, NO_2, NO_x are within the national second-standard level of air quality in spring, summer and fall, but much worse in winter, reaching low to mid alert level of air pollution. Since 1999, the concentrations of SO_2, NO_2, and NOx have been decreasing. However, the concentrations of PM_{10} and TSP have been increasing, and become major pollutants.
The mean concentration of PM_{10} is 2.56 mg m^{-3}. Even in summer the air pollution due to PM_{10} is at low alert level. The rate of polluted-day occurrence is 71% in a year, 89% in winter, and 79% in spring. Starting from November, the air pollution due to PM_{10} intensifies, and reaches mid to high alert level of air pollution, and continues until April next year. The mean concentration of TSP is 5.92 mg m^{-3}, which is higher than the air quality standard. In winter and spring, the TSP concentration is 2-10 times higher than the third-standard level of air quality. Intrinsic factors and exterior preconditions for increase of PM_{10} and TSP are discussed such as the propagation of dust storms.

Key words: Lanzhou, pollutants, total suspended pollutants, observational data analysis, dust-storm,

INTRODUCTION

Lanzhou is located at a narrow (2-8 km width), long (40-km), NW-SE oriented valley basin (elevation: 1,500-m to 1,600-m) with the Tibetan plateau in the west, Baita mountain (above 1,700-m elevation) in the north, and the Gaolan mountain in the south (Fig. 1a). The topographic characteristics make Lanzhou vulnerable to the invasion of dust storms (Fig. 1b). The aspect ratio of the valley (depth versus width) is around 0.07, which blocks the air streams due to the large frictional forces and causes weak winds and stable stratification (even inversion) to inhibit turbulent diffusion. The meteorological conditions (low winds, stable stratification especially inversion) cause the pollutants difficult to disperse. These conditions make Lanzhou one of the most polluted cities in China (Fig. 1c).

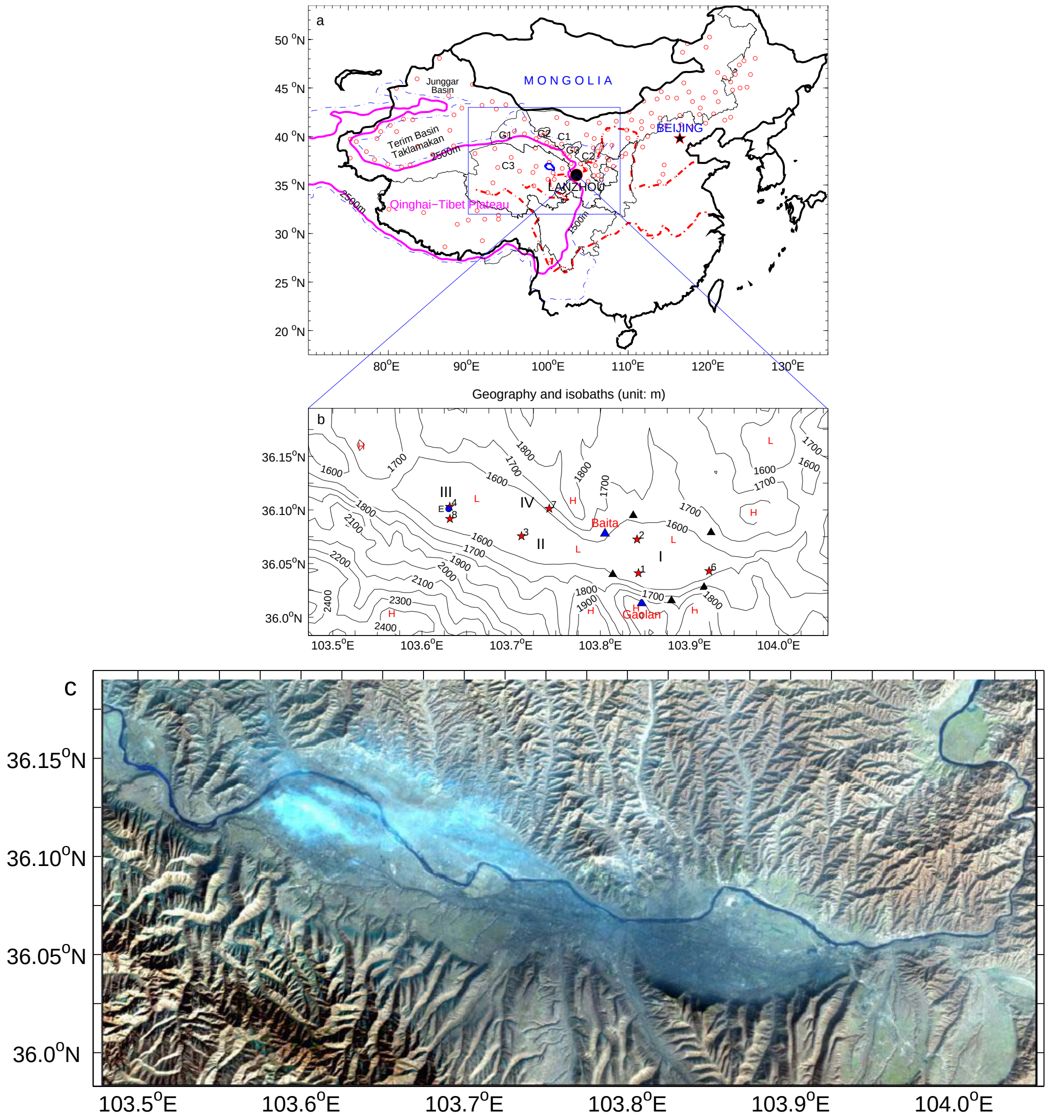

Figure 1: Lanzhou: (a) geography, (b) topography, and (c) LANDSAT-TM imagery representing air pollution on 3 January 2001.

Since mid 1990s, the local Lanzhou government has conducted afforestation on the mountain slope and shut down several factories that emitted large amount of pollutants. The gaseous pollutants such as SO_2 and NO_x concentrations have been reduced. However, the particulate pollutants such as TSP and PM_{10} still keep high concentrations [Chu et al. 2004]. Fig. 2 shows the evolution of annual mean concentration for the three major pollutants (SO_2, NO_x, TSP) measured at the local environmental protection agency (EPA) station (103.631°E, 36.103°N), which is marked as the solid circle in Fig. 1b. The annual mean SO_2 has a maximum near 0.12 mg m^{-3} (above the third level standard: 0.10 mg m^{-3}) in 1994, and decreases monotonically to 0.055 mg m^{-3} (below the second level standard: 0.06 mg m^{-3}) in 2000 (Fig. 2a). The annual mean NO_x has two maxima (above the third level standard: 0.10 mg m^{-3}) in 1990 and 1995, and decreases monotonically to 0.05 mg m^{-3} (close to the second level standard: 0.05 mg m^{-3}) in 2000 (Fig. 2b). The annual mean TSP concentration is always above the third level standard: 0.3 mg m^{-3} (Fig. 2c). What is the reason to cause high concentration of the particulate pollutants?

An air-quality monitoring system has been established in Lanzhou with multiple sampling and sufficient numbers of stations. This is the part of the project entitled Air Pollution and Control in Lanzhou (APCL), supported jointly by Gansu Province and the Chinese Academy of Sciences and carried out from 1999 to 2001.

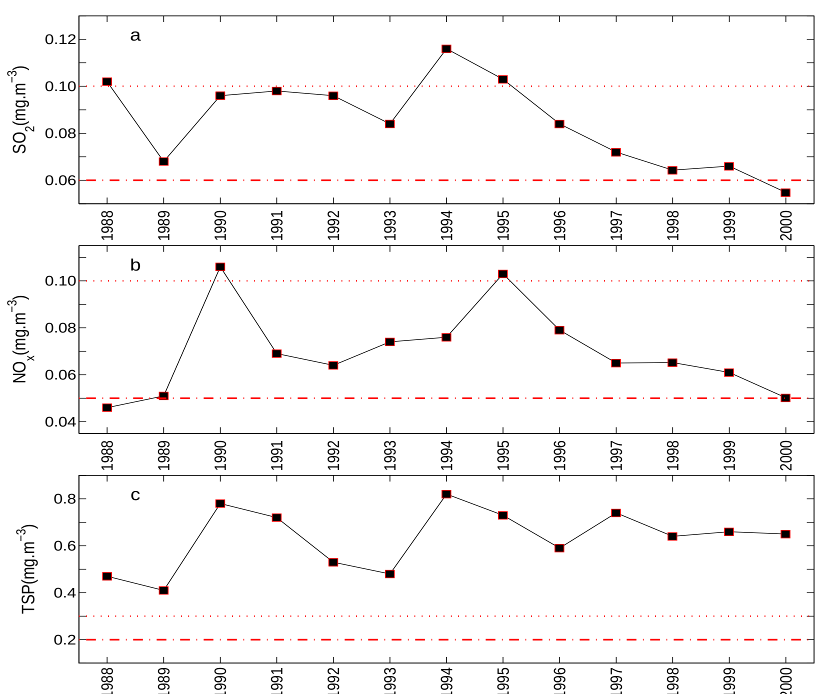

Figure 2. Annual mean concentration (mg m^{-3}): (a) SO_2, (b) NO_x, and (c) TSP measured at the local EPA station (103.631°E, 36.103°N), which is marked as the solid circle in Fig. 1b. The second-level standard is represented by the horizontal dash-dotted line and the third-level standard is represented by the horizontal dotted line.

In this study, detail analyses are conducted on the concentration data collected by the air-quality monitoring system as well as the associated meteorological conditions. The objectives are to detect temporal and spatial variability of various pollutants, to evaluate the air-quality objectively and quantitatively, to analyze the pollutant sources, and to find the favorable meteorological conditions for the pollutant dispersion.

2. DATA

The data are from several sources: the APCL project, routine air-quality observations (Table 1), and routine meteorological observations. From the APCL project, the air quality data were collected at observational stations (St-1 - St-5) from October 1999 to April 2001 and at observational stations (St-6 - St-8) from August 2000 to April 2001. Over these stations, daily concentration of SO_2, NO_x and TSP is calculated. The data from routine air-quality observations include daily concentrations of SO_2, NO_2, PM_{10} collected continuously by the local Environmental Protection Agency (EPA) in Lanzhou from June 2000 to May 2001 (station-E in Fig. 1b). Annual mean concentrations of SO_2, NO_x and TSP are collected and computed from surface meteorological stations.

Table1. Location of observational stations and mean concentrations (mg m^{-3}) of major pollutants measured during the whole observational period. Note that the second-level annual mean standards of air quality are (0.06, 0.05, 0.20) mg m^{-3} for (SO_2, NO_x, TSP).

Site	Longitude E	Latitude N	Height Above Surface (m)	Region	SO_2	NO_x	TSP
St-1	103.84	36.04	25	Chengguan (District-1)	0.08	0.06	0.69
St-2	103.84	36.07	11	Chengguan (District-1)	0.03	0.04	0.57
St-3	103.71	36.08	15	Qilihe (District-3)	0.05	0.05	0.74
St-4	103.63	36.10	22	Xigu (District-2)	0.08	0.06	0.68
St-5	104.09	35.84	4	Yuzhong County	0.01	0.01	0.28
St-6	103.92	36.04	19	Chengguan (District-1)	0.02	0.03	0.56
St-7	103.74	36.10	15	Anning (District-4)	0.04	0.05	0.52
St-8	103.63	36.09	4	Xigu (District-2)	0.06	0.05	0.54

4. TSP CONCENTRATION

The daily mean TSP concentration is larger than the second-level standard (0.3 mg m^{-3}) almost all the time and than the third-level standard (0.5 mg m^{-3}) sometimes (Fig. 3). The monthly mean TSP concentration exceeds the second-level daily mean TSP standard (0.3 mg m^{-3}) all the time at all the ACPL stations in the urban area of Lanzhou. Even in the background station (St-5) located in the countryside, the monthly mean TSP concentration often exceeds the second-level daily mean TSP standard. The monthly maximum TSP concentration in the background station (St-5) always exceeds the second-level daily mean TSP standard and even exceeds the third-level daily mean TSP standard (1.0 mg m^{-3}) quite often. At the seven urban ACPL stations, the monthly maximum TSP concentration often exceeds the third-level daily mean TSP standard.

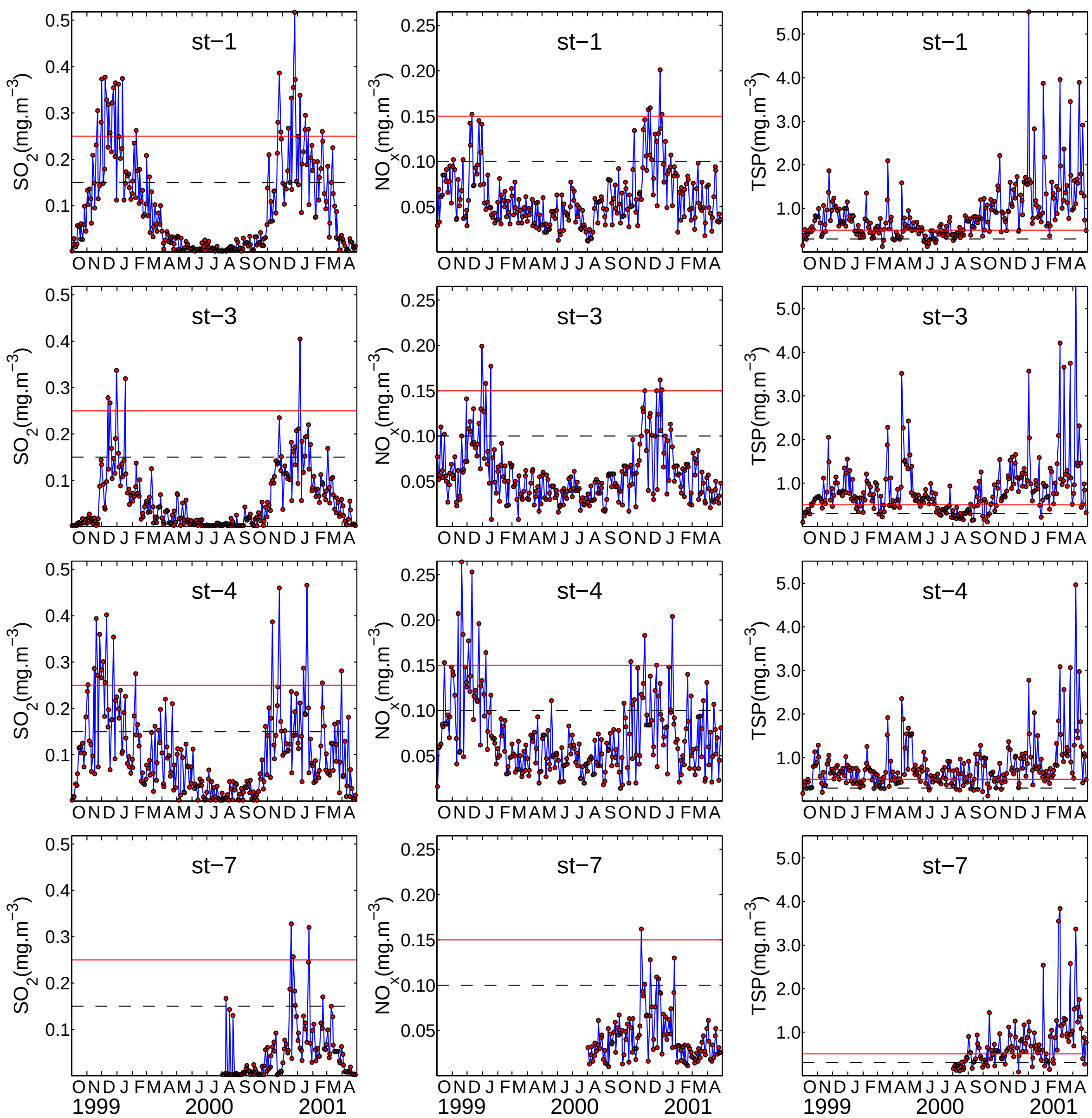

Figure 3. Daily mean SO_2, NO_x, and TSP concentrations (mg m^{-3}) at St-1, St-3, St-4 and St-7. Horizontal dashed line is daily mean second-level standard, while horizontal solid line is daily mean third-level standard. Note that the daily mean TSP concentration is usually above the second-level standard.

The TSP concentration has an increasing tendency (Fig. 4). Among the eight ACPL stations, five stations (St-1 to St-5) have two years' data. To filter out the seasonal effect, the monthly mean TSP concentrations (mg m^{-3}) of the same month between period-1 (October 1999 - April 2000) and period-2 (October 2000 - April 2001) are compared. The monthly mean TSP concentration is more in period-2 than in period-1 all the time. The monthly maximum TSP concentration is more in period-2 than in period-1 almost all the time.

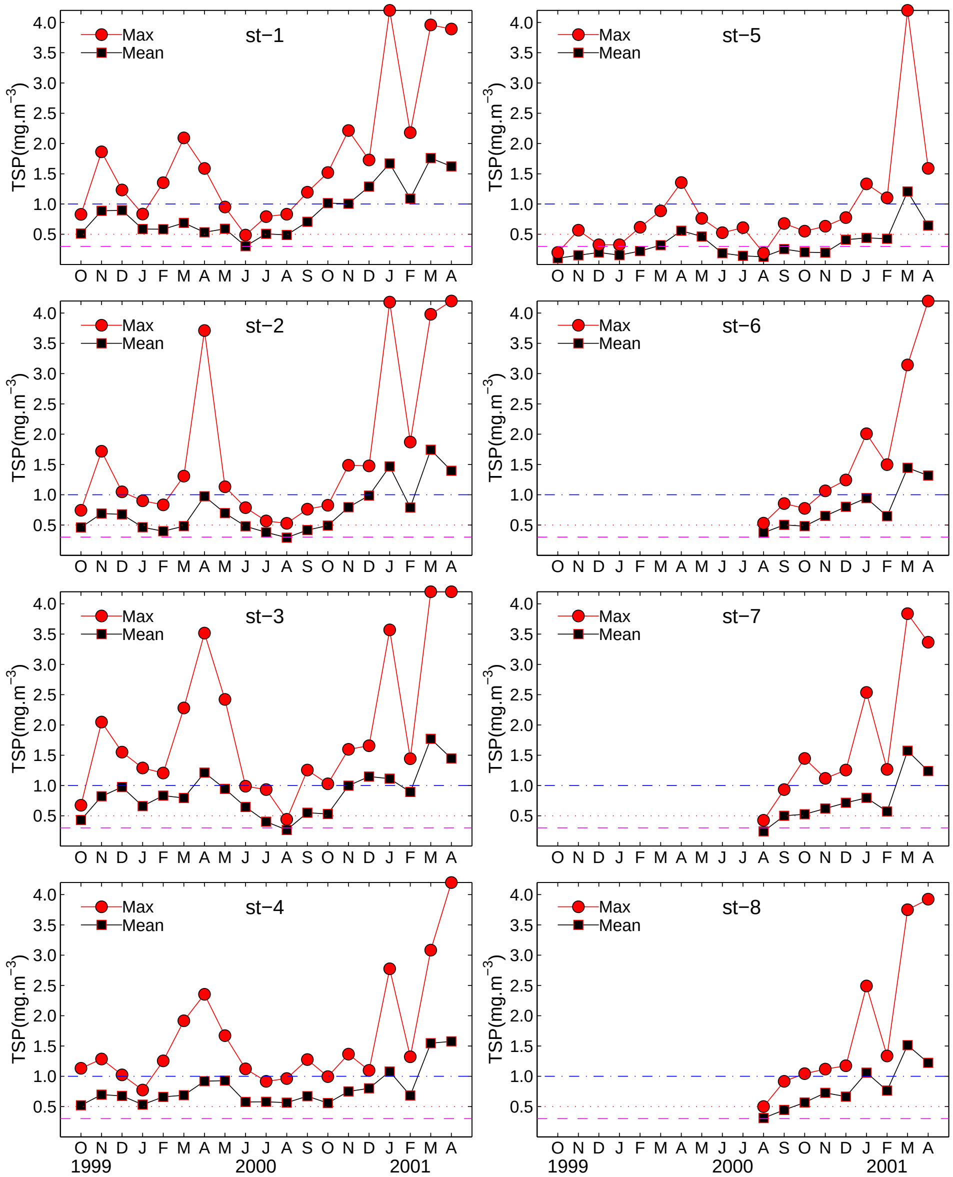

Figure 4. Monthly mean(■) and maximum(●) concentrations(mg m^{-3}) of TSP at St-1 to St-8.

Air pollution index (API) is a quantitative measure for uniformly reporting the air quality for different constituents and connects to the human health. CEPA classifies the air quality standards into 5 major categories due to API values (Table 2): I (clean), II (good), III (low-level pollution), IV (mid-level pollution), and V (high-level pollution). The categories III and IV have two sub-categories: (III_1, III_2) and (IV_1, IV_2).

Table 2. API and air quality management in China.

Air Pollution Index	Air Quality Classification		Air Quality Description and Management
API ≤ 50	I	Clean	No action is needed.
50 < API ≤ 100	II	Good	No action is needed.
100 < API ≤150	III_1	Low-level pollution	Persons should be careful in outdoor activities.
150 < API ≤200	III_2		
200 < API≤ 250	IV_1	Mid-level pollution	Persons with existing heart or respiratory illnesses are advised to reduce physical exertion and outdoor activities.
250 < API≤ 300	IV_2		
API ≥300	V	High-level pollution	Air pollution is severe; The general public is advised to reduce physical exertion and outdoor activities.

Monthly mean API of SO_2, NO_x, and TSP for the eight observational stations shows the similar fact that the TSP pollution is much more series than the SO_2, and NO_x pollutions and the SO_2 and NO_x pollution has seasonal variation with larger value in winter and much smaller value in other seasons. At the background station (St-5), API for SO_2 and NO_x is less than 50 all the time (Fig. 5).

Monthly mean API for TSP is large even in the background station (St-5) with the value larger than 200 during April-May 2000 and January-April 2001 (Fig. 5). It is always greater than 200 during the whole observational period at St-4 with a maximum value above 600 in March 2001. At the other stations, it is generally greater than 200 (but always larger than 100) during the period except in summer 2000. March 2001 is one of the severely polluted months of TSP. The maximum API for TSP at all eight stations is greater than 500. The monthly mean API of TSP is greater than 500 in all the city stations with 400 in the background station (St-5).

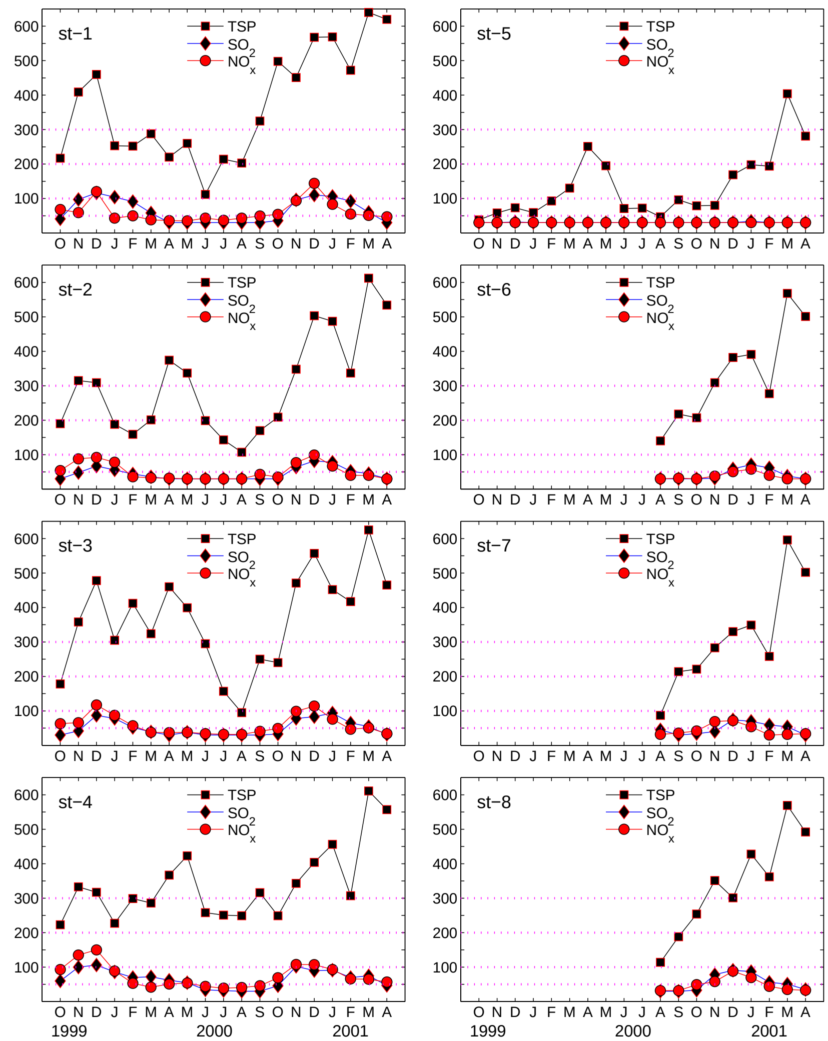

Figure 5. Monthly mean API at St-1 to St-8. Here, the symbol '♦' represents SO_2, '●' represents NO_x, and '■' represents TSP.

5. DUST-STORM AND TSP-PM_{10} POLLUTIONS

As described in Section 5, TSP and PM_{10} are the most series pollutant in Lanzhou. Occurrence of high TSP and PM_{10} concentrations are associated with the propagation of dust storms. For example, Fig. 6 shows January 2001 daily TSP concentrations at the background station (St-5) and spatially averaged over seven (St-1 to St-4 and St-6 to St-8) city stations are illustrated in panel-a, and the daily PM_{10} concentration at St-E is shown in panel-b. On the two panels the dust-storm is marked by the symbol 'S'. Dust-storms occur quite often in the vicinity of Lanzhou: 9 days in January 2001. For example, during the dust-storm from December 31, 2000 to January 1, 2001, dusts float in the sky for 7 days (January 1-5, 2001) [Ding et al., 2001], and causes high TSP and PM_{10} concentrations on January 1, 2001 (TSP: 3.08 mg m^{-3} and PM_{10}: 2.56 mg m^{-3}) and on January 2, 2001 (TSP: 1.75 mg m^{-3} and PM_{10}: 2.01 mg m^{-3}).

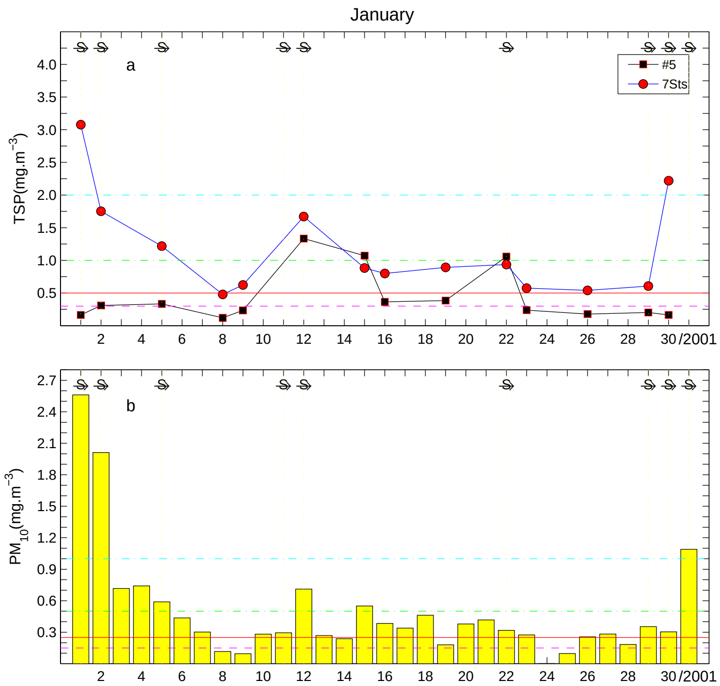

Figure 6. Daily mean (a) TSP, (b) PM_{10} concentrations (dust storm represented by the symbol '$) and (c) horizontal distribution of dust storms (solid dots) in January 2001.

Deserts and barren lands are widespread in the northwest of China and they are expanding attributing to underdeveloped methods of producing and management, and irrational utilization of resources. Aridness and desertization cause frequent dust storms [Zhu, 1999; Dong et al., 1999; Wang and Cheng, 1999]. The dust storms that directly cause severe particulate pollution of Lanzhou are mainly generated in neighboring regions such as Hexi Corridor (Fig.1a marked by G1, G2, G3), Badanjilin desert (100°~103°E, 39°~42°N, centered at C1), south of Tenggeli desert (103°~106°E, 37°~39°N, centered at C2), and Caidam desert (about 92°~98°E, 36°~38°N, centered at C3). These regions are enclosed as a ladder-shaped region (Fig 1a). When the air is dry, strong winds blowing over the deserts cause the dust-storms and in turn brings high TSP and PM_{10} concentrations in Lanzhou.

8. CONCLUSIONS

(1) For the past ten years, the gaseous pollutions such as SO_2, NO_2, NO_x have been improved in Lanzhou. The annual mean SO_2, NO_2, NO_x concentrations decrease steadily

from 1995 to 2000. However, the pollutions of PM_{10}, TSP have been worsened, and become the major pollutants in Lanzhou.

(2) TSP pollution is very series in Lanzhou with 2~10 times greater than the third level standard in winter and spring. March 2001 is the most severely polluted month with API ＞500 all the time. The high-level TSP pollution (API > 300, category V) occurs frequently with 68% in spring, 16% in summer, 45% in fall, and 63% in winter.

(3) Dust-storms occur quite often in the vicinity of Lanzhou (9 days in January 2001, 3 days in February 2001, 9 days in March 2001, and 12 days in April 2001), and cause high TSP and PM_{10} concentrations in Lanzhou. The maximum TSP concentration was observed as 5.29 kg m^{-3} (March 2001). Reduction of the TSP and PM_{10} concentrations is an urgent issue for air quality control in Lanzhou and related to the reduction of dust storms in the vicinity. This may be achieved by the improvement of the land surface characteristics such as long term forestation and vegetation.

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