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Characteristics and origins of a typical heavy haze episode in Baotou, China: implications for the spatial distribution of industrial sources

Key words: Air pollution, Haze, Industrial sources, Backward trajectory, Conditional probability function

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Introduction

- Air pollution in China has become the most concerning environmental problem and the identification of its sources is vital to clarify the mechanism of formation of heavy haze.
- The characteristics of pollution in Baotou are different from those of the "coal burning-vehicle composite pollution" in the developed areas.
- We discuss the characteristics of air pollution and the impact of cross-border transport and local emissions of pollutants in Baotou from 12-25 December, 2013. And the effect of industrial spatial distribution on haze formation and future controlling strategies in Baotou are also studied in this paper.

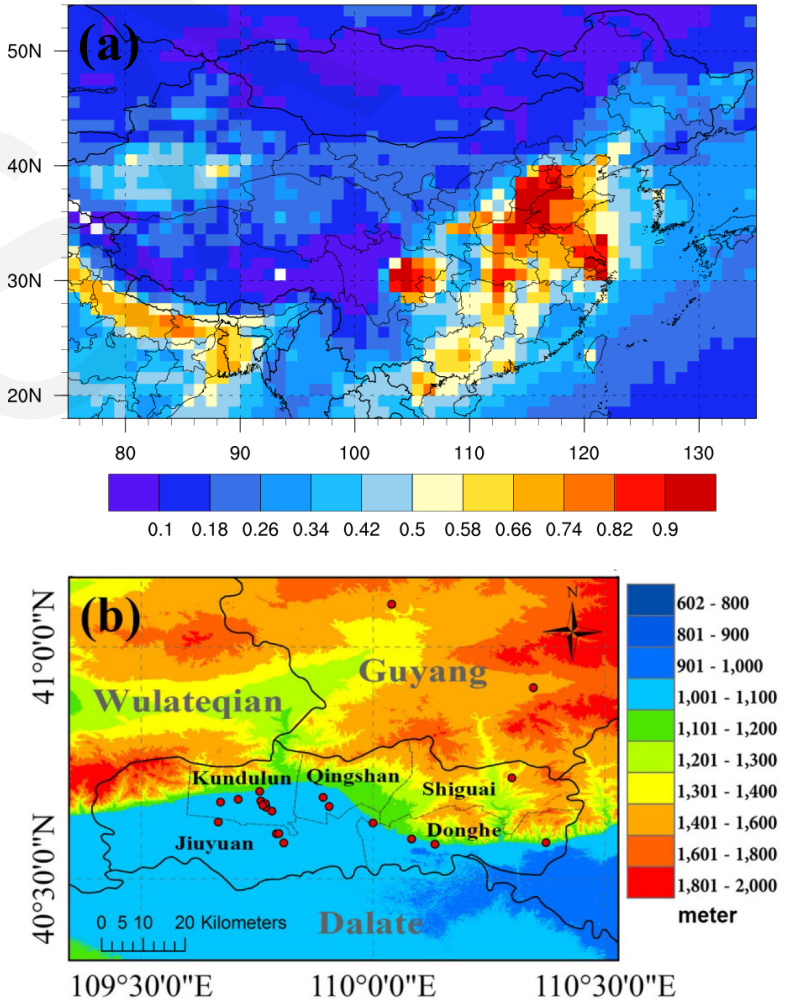

Fig 1. (a) AOD at 550 nm in 2013, (b) The topography of Baotou

Methods

➢Ground observations, MODIS and meteorological data

Data were obtained from the China National Environmental Monitoring Center, the Baotou Environmental Protection Agency, the Inner Mongolia Self-monitoring Information of Key Supervision Enterprises Publishing Platform, Aqua MODIS and the China Meteorological Data Sharing Service System.

➢Air mass back trajectory

The meteorological data input to the trajectory model were obtained from WRF outputs and 48-h backwards trajectories of air masses arriving in Baotou were calculated eight times per day.

➢Conditional probability function

$$CPF(\theta) = \frac{m_{\Delta\theta}}{n_{\Delta\theta}}$$

The surface data used by CPF analysis were accessed from WRF modeling and the upper 25th percentile of the fractional contribution from the sources was set as the threshold criterion.

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Results

➢AOD analysis revealed that the south or southeast regions of China suffered the heavy haze before Baotou during the study period

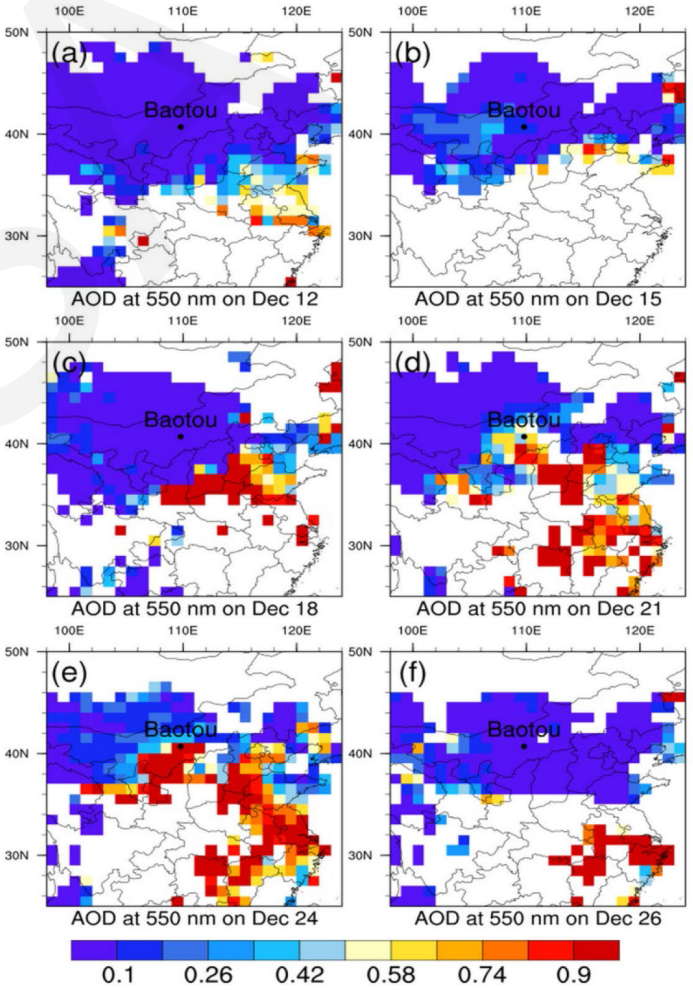

Fig 2. Satellite observations of daily average AOD at 550 nm on (a) 12 December, (b) 15 December, (c) 18 December, (d) 21 December, (e) 24 December, and (f) 26 December , 2013

Results

➢While backward trajectories showed that most of the air masses arriving in Baotou originated from the west, northwest, north, and northeast regions in the atmospheric surface layer (100 m above ground) and upper air (500 and 1000 m above ground). None of the air masses originated from the heavy haze regions such as south and southeast regions.

➢Combined with AOD analysis, there was no obvious haze cloud or dust storm in the upwind regions throughout the period.

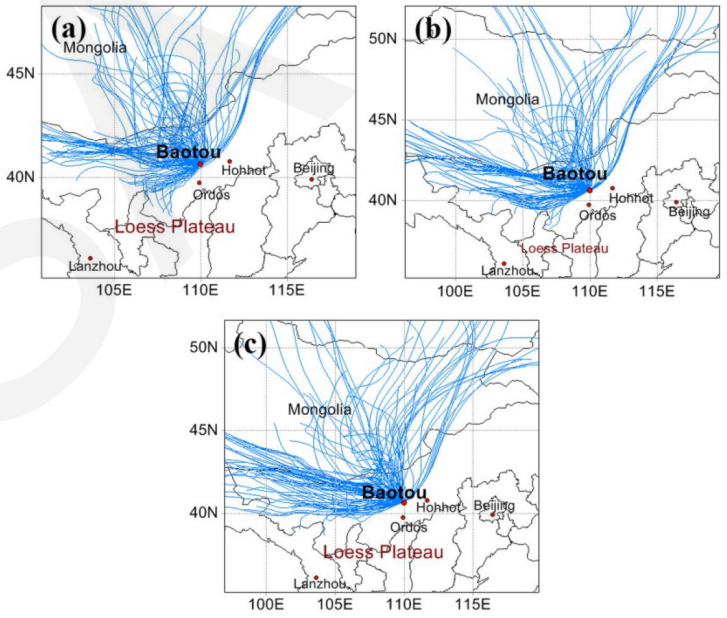

Fig 3. 48-h backward trajectories of air flows in Baotou at different altitudes: (a) 100 m, (b) 500 m, (c) 1000 m

➢Therefore, long-range transport of pollutants via wind flow from polluted areas to Baotou might not have occurred and this finding indirectly supports that the sharply increase of pollutants concentration in Baotou on 24 December was mainly due to high emissions from local anthropogenic sources.

Results

- Figs. 4a-4d showed that the CPFs were high when winds were from the south, southwest, and west. These high CPFs could be attributed to the high intensity of industrial emissions in the upwind regions (Kundulun and Jiuyuan districts) (Fig. 5)

- Figs. 4e-4f showed higher CPFs were observed in the eastern sectors. There was a power plant and an aluminum manufacturer located in the east (Fig. 5), and the high intensity emissions from these two sources could have contributed to the high CPFs.

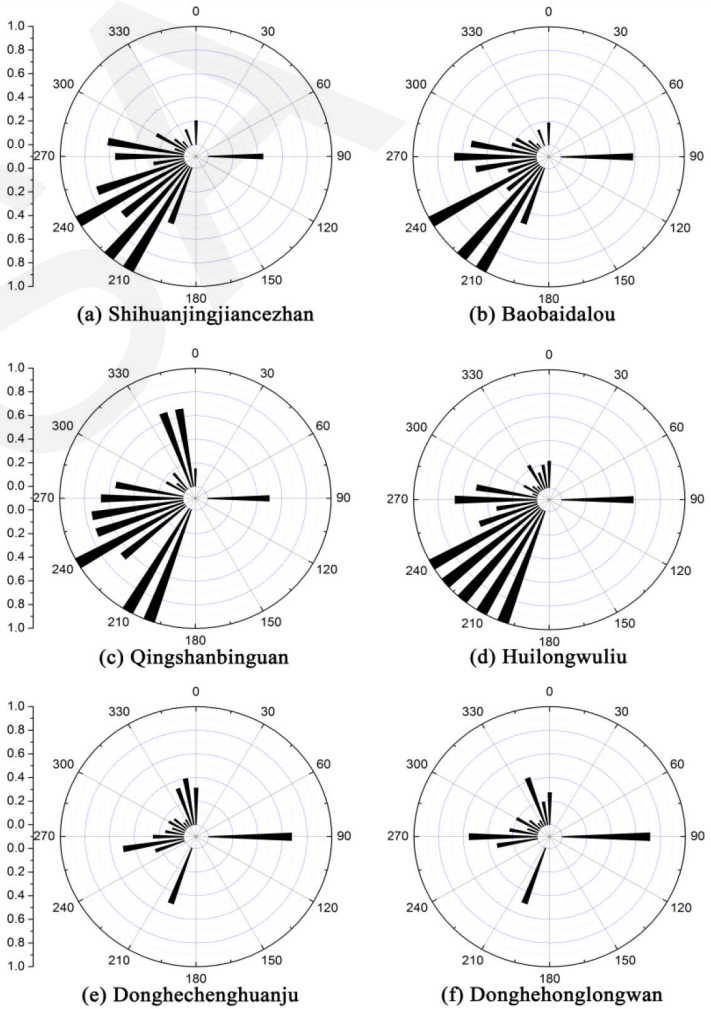

Fig 4. CPFs results at different monitoring stations: (a) Shihuanjingjiancezhan, (b) Baobaidalou, (c) Qingshanbinguan, (d) Huilongwuliu, (e) Donghechenghuanju, (f) Donghehonglongwan

Results

➢The low speed of south or southwest winds and the mountainous terrain north of the city were unfavorable for the diffusion of pollutants.

➢This suggests that the non-prevailing winds, such as low-speed south and southwest winds, should not be ignored though they occur infrequently during winter.

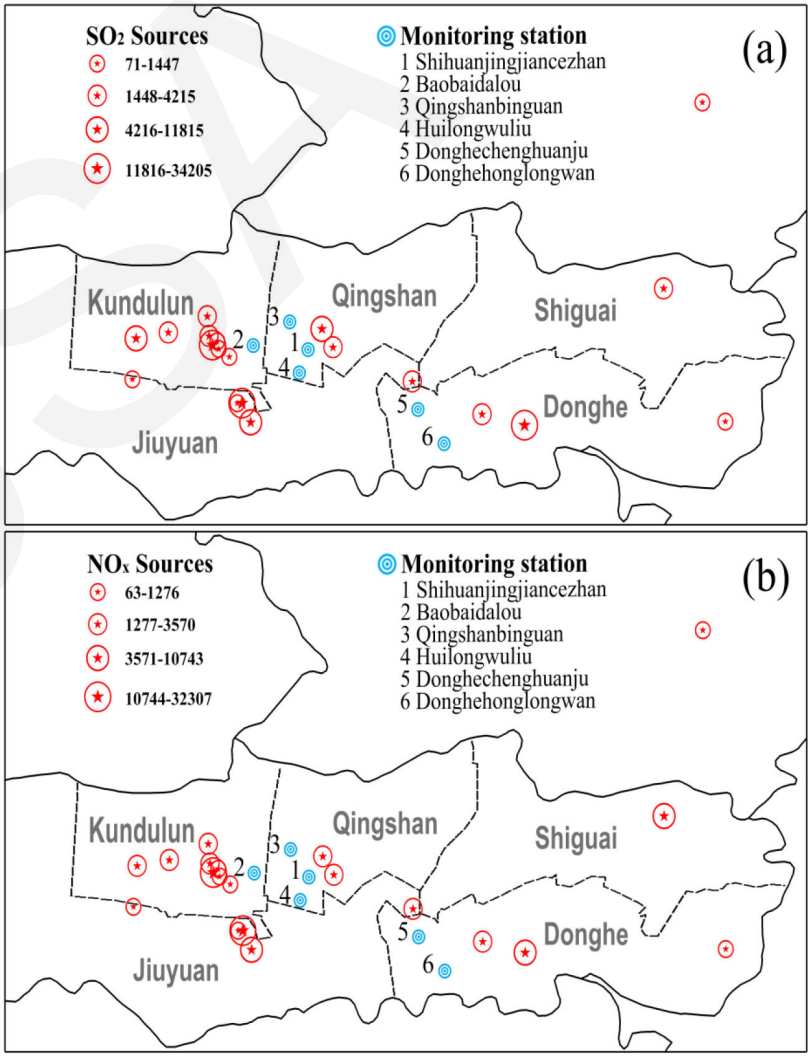

Fig 5. Emissions from the main industrial sources in urban areas of Baotou in 2013 for: (a) SO_2, (b) NO_X

Conclusions

- The analysis of MODIS-derived AOD combined with air mass trajectories suggested that cross-border transport of pollutants did not influence the heavy haze event in Baotou.

- According to the CPF analysis, the elevated $PM_{2.5}$ concentrations in urban areas could be explained by the south and southwest winds and high emissions in the upwind regions, because these low-speed winds and the north mountains were unfavorable for the diffusion of pollutants.

- The present study indicated that besides the prevailing winds, the influence of non-prevailing winds with low speed should also be taken into consideration in the future when governments attempt to optimize the industrial layout in urban areas with a high intensity of industrial emissions.