THE BEIJING CITY AIR POLLUTION OBSERVATION EXPERIMENT (BECAPEX) AND SOME PRELIMINARY RESULTS

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ABSTRACT. The Beijing City Air Pollution Observation Experiment (BECAPEX) is the most comprehensive field program carried out to date to characterize the air pollution sources and processes in and around Beijing City. A key issue the BECAPEX experiment addresses is whether the air quality in the Beijing Metropolitan area (BMA) can meet the standards in 2008 set by the Beijing Olympic Organizing Committee by controlling the emissions within BMA. Observations from BECAPEX revealed that the air quality BMA is a regional problem. Although reduction of emissions within BMA can generally improve its air quality, under certain weather conditions, transports by local head island circulation, synoptic and large-scale winds can carry pollutants from regions to the south and east of the BMA. These multi-scale transports play a crucial role in determining the air quality in the BMA. Thus, in order to properly address its air pollution issue, Beijing and its neighboring region must be considered as an integrated system, where pollution control strategies must be formulated synergistically.

The "Beijing City Air Pollution Observation Experiment" (BECAPEX) conducted in Beijing City and its surrounding region in spring 2001 and summer 2003. A three-dimensional observing network utilizing grand-based observations and space-based satellite remote sensing was setup to monitor the urban environment in and surrounding Beijing. It was the first comprehensive air pollution monitoring attempt around Beijing city utilizing advanced observing instruments including atmospheric profiler, tethersonde, ultra-sonic anemometer sodar and lidar, lower boundary micro meteorology gradient observation system, roof-mounted pollutant observation and collection instrument, 10 level atmospheric hemistry profiler mounted on a 325 m tower, a 3 level aerosol observation system, as well as satellite remote sensing. The focus of the field experiment was on the environmental dynamics of air pollution, a central issue concerning the formation mechanism, control and mitigation of the effect, of air pollution. The purpose of the experiment was to characterize the three-dimensional physical and chemical structure of the atmospheric planetary boundary layer (PBL) surrounding Beijing area, and to obtain a coherent three-dimensional depiction of various scales of boundary layer phenomenon, such as urban heat island, urban lee wind, street circulation, etc.[Figure1-3]

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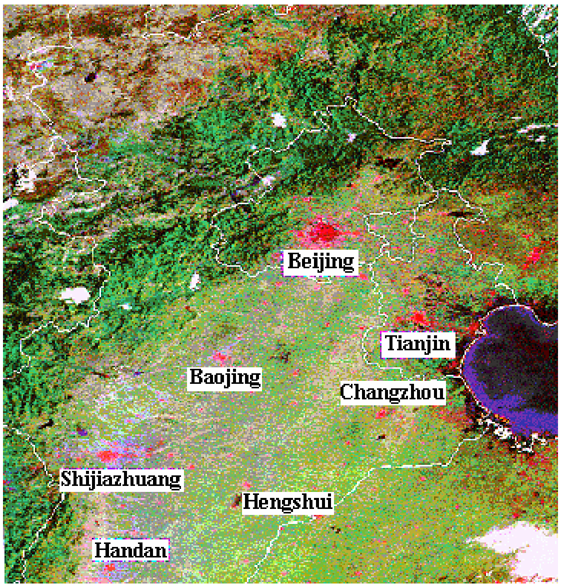


Figure 1 The "heat island cluster" surrounding the metropolitan areas of Bejing, Baoding, Shijiazhuang cities as seen from satellite (Source: China National Satellite Meteorological Center).

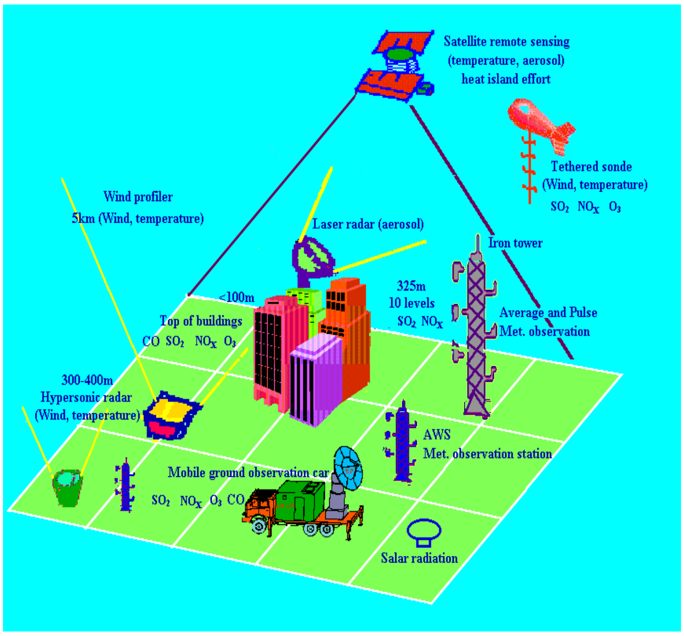


Figure 2. A schematic depiction of the three-dimensional observing system used to characterize the three-dimensional physical and chemical structure of the atmospheric

The results from the BECAPEX experiment provided a detailed three-dimensional description of the dynamic and thermal structure of Beijing's urban atmospheric environment, the physical and chemical characteristics of air pollutants, their variation, transportation, diffusion and transformation, and impacts on regional weather and climate. Key findings of the BECAPEX are summarized below.

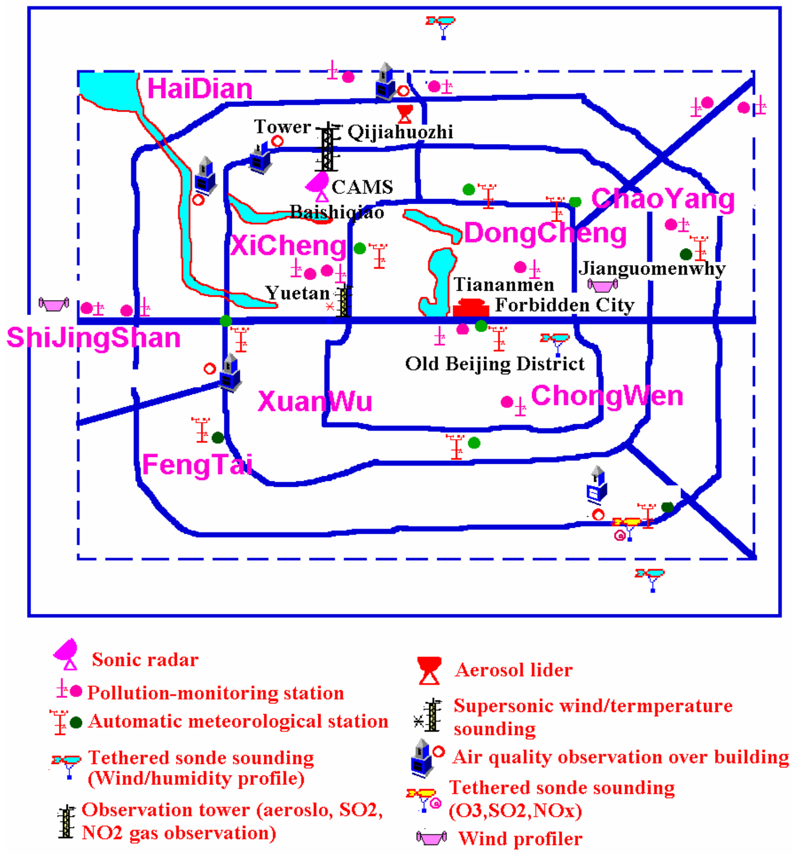


Figure 3. Distribution of observational stations for air pollution in urban atmosphere boundary layer (Xu, 2002).

1)Discovery and physical characterization of the BMA "air dome": The observations revealed the existence of an "air dome" (a dome-shape boundary layer) around the urban area of Beijing and provided a comprehensive set of parameters that define the characteristics of the air dome (Fig. 4). During severe air pollution periods in the winter season, the "air dome" is characterized by the presence of multiple inversion layers that show clear diurnal variation. The inversion height increases during the day and decreases and thickens at night, leading to a secondary, near-surface inversion below the main inversion layer located between 200–400 m. Another feature within the BMA urban air dome is the presence of low wind speed "stagnation area" associated with building clusters. The wind speed in the "stagnation area" is usually less than 2–3 m/s and follows the logarithmic law. The friction length in the BMA boundary layer ranges between 0.4–0.7 m in dense low building areas, and 0.7–1.7 m in regular tall building areas. Heat flux within 300 m of the surface follows the constant flux approximation. Comparisons between urban and rural stations indicate the presence of heat island effect, which is characterized by a 4^{o} C temperature difference during sunny days and 2^{o} C in cloudy days, as well as a thicker temperature inversion and wind shear layer in urban areas.

2)Characterization of air pollution within the BMA "air dome": the vertical profile of air pollution is associated with the thermodynamic structure of the "air dome". Within the "air dome", there are three typical pollution high concentration layers, located at 30 – 40 m, 100 m, 200 – 300 m, respectively. The height of the pollution concentration layers varies according to weather conditions. The height of the "pollution dome" can reach 300 – 400 m in some cases. The roof-top observations of hourly SO_2, NO_x, O_3, CO taken at different height and locations show spatial and temporal coherence. NOx is the main specie of pollutants and is correlated with SO_2, NO_x, and CO all peak at around 9:00 am local time, and reach their low in the afternoon. O_3 shows an opposite trend, peaking in the afternoon. We have observed several near-zero O_3 concentration events during inversion. TSP shows a clear decreasing trend with height. Over 60% of TSP is within the PM2.1 range. The concentration and distribution of aerosol TSP is strongly modulated by weather processes. Low wind, inversion, and high humidity are typical conditions for increased TSP concentration.(Figure 5)

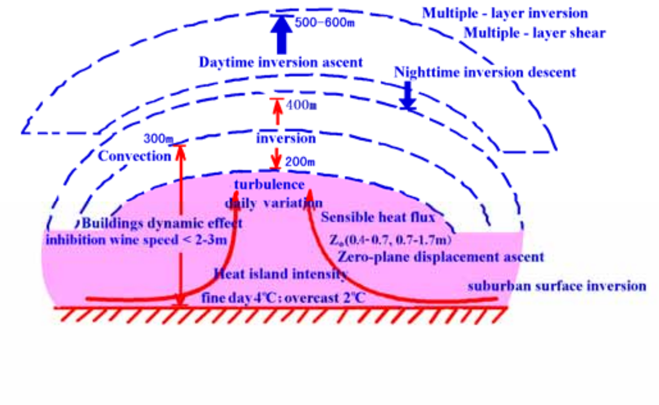


Figure 4　Integrated schematic of city air dome dynamic stru

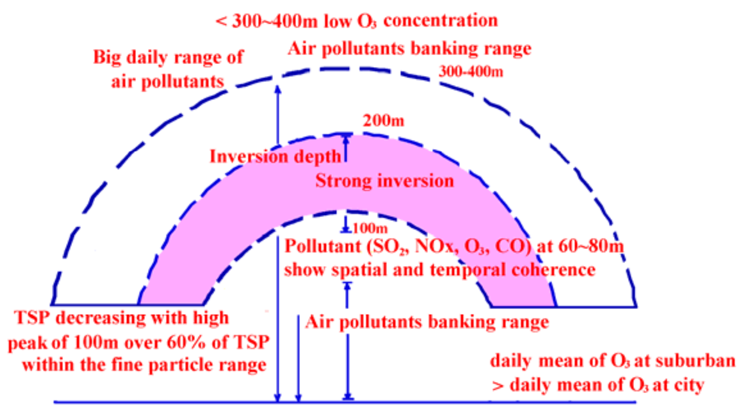
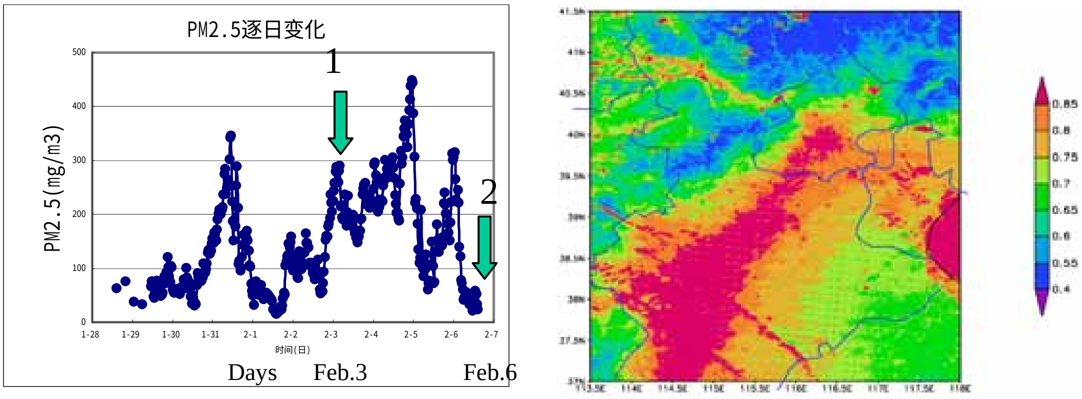


Figure 5　3-D structure of city air pollution

3)Multi-scale air pollution transport: the transport and distribution of air pollutants were related to the multi-scale interaction among large-scale circulation, mountain and valley wind, and urban heat island circulation. Urbanization enhanced the heat island effect. Local circulations associated with the heat island effect acted as a local transport mechanism which transports pollutants from surrounding regions to urban centers. At regional scales, southerly synoptic winds transport pollutants from the areas south and east into BMA. This is mainly because of the "horseshoe shaped" topographic feature surrounding the relatively low-elevation Beijing city, allowing a transport pathway from the south and east of Beijing. This is also confirmed by the correlation between the change of aerosol index in Beijing area and the aerosol indexes in its surrounding area, particularly in regions to the south and east of Beijing. Thus, there is a clear need to recognize clustered pollution sources and their interaction within the city group surrounding Beijing.



(a) (b)

Figure 6 (a) Ground-observed PM2.5 in Jan.1-Feb.7, 2002 at top of Dance Institute building at height 40m (arrow 1 and 2 denote the peak and low point, respectively (b) Variational corrected field of satellite remote sensing aerosol optical thickness by ground-observed PM10 on February 3, 2002

1) From 1980 to 2000, air pollution associated with urbanization and economic development in Beijing and its surrounding region resulted in an increase of fog and smog days and reduced visibility in Beijing during the summer, while winter season fog frequency and visibility experienced an opposite trend, suggesting the air quality in Beijing and its effect on local climate and weather are sensitive to seasonality, perhaps in response to the seasonal reversal of the prevailing summer and winter monsoon wind directions which affect air pollution transport processes.

Concluding Remarks The BECAPEX experiment brought together an interdisciplinary team to address the air pollution issue in and around Beijing. Although we have focused on Beijing City, the work carried out in this study has significance for other large urban centers generally. While each city has its unique air pollution problem in association with its social and economic development activities, the need for a holistic approach to the complex environmental problems is the same.

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