Potential Sources of Air Pollutant in Panjin

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Abstract. The Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT), potential source contribution function (PSCF) were used to identify the transport pathways and identify potential sources of air pollution in Panjin. Three haze events were occurred in the campaign: period 1 (Nov. 2-3), period 2 (Nov. 6-14) and period 3 (Nov. 29-30) during November, 2015. The back-trajectories and PSCF analysis of three haze episodes show different air transport paths, however, Inner Mongolia and Liaoning province mostly affects the air quality of Panjin. Thus, it is necessary to enlarge degree of pollution prevention and treatment in Inner Mongolia and Gansu province to improve air quality at Panjin.

Introduction

Panjin, located in the central zone of Liaohe River Delta, is a big city in northern China with an area of 4071 km\textsuperscript{2} and population of 1.3 million. Considering the poor air quality in Panjin, the local government implemented a series of air pollution control measures. However, according to the government statistics, the annual average of PM\textsubscript{2.5} concentrations of 2015 in Panjin was 51 µg/m\textsuperscript{3}, 0.5 times than the annual average concentration of PM\textsubscript{2.5} Grade II standard. An increasing trend in the severity and frequency of PM pollution in more recent years has been observed in megacities\textsuperscript{[1-3]}, but only limited data have been reported for Panjin pollution characteristics. It is useful to understand its spatial distribution and potential sources of haze pollution.

In this study, given that the haze pollution episodes easily occur in the heating season, the hourly and daily concentrations of the air pollutants (SO\textsubscript{2}, NO\textsubscript{2}, CO, PM\textsubscript{2.5}, PM\textsubscript{10}) in Panjin, obtained from the national observation station data, were analyzed during the period of November 1 to 31, 2015. The main objectives of this study is to identify the transport pathway and potential sources of PM\textsubscript{2.5} by using backward air parcel trajectories The findings presented are helpful to understand the characterizations and sources of PM pollution at Panjin, providing a scientific and effective basis for making future PM pollution control policies.

Methodology

Ground Observations and Meteorological Data

Hourly concentrations of air pollutants (SO\textsubscript{2}, NO\textsubscript{2}, CO, PM\textsubscript{2.5}, PM\textsubscript{10}) at three urban national observation stations in Panjin were acquired from the China National Environmental Monitoring Center (CNEMC). The data presented in this study were obtained for the period of Nov. 1 to Nov. 31th. The assurance/quality control (QA/QC) procedures for monitoring strictly follow the national standards (State Environmental Protection Administration of China, 2006). These observation sites include Kaifaqu (KFQ), Xinlongtai (XLT) and Xinshengjiedao (XSJ), as seen in Figure 1.
Air Parcel Back Trajectory

In order to better understand the transport of airborne particles from distant sources and the pathway of the air mass, backward trajectories simulations were conducted using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) 4.0 Model developed by NOAA/ARL \(^{[4]}\) (with meteorological data from the Global Data Assimilation System, GDAS) (http://www.rl.noaa.gov/ss/transport/archives.html). Trajectories extending 3 days (72 h) into the past were estimated for every hour on each day. The trajectories from each site were calculated starting at 500 m above ground level (AGL).

PSCF and CWT analysis

The PSCF method is based on air mass residence time allocations over specific regions in order to identify the potential sources of aerosols affecting air quality in urban areas. The PSCF value can be interpreted as the conditional probability with concentrations that are higher than a given criterion value and related to the passage of air parcels through a grid cell with this PSCF value in their pathways to the receptor site.

The PSCF values for the grid cells were calculated by counting the trajectory endpoints that terminated within each cell by the following equation (1):

$$PSCF_{ij} = \frac{m_{ij}}{n_{ij}}$$

(1)

Where PSCF\(_{ij}\) is the conditional probability value grid cell \((i,j)\), \(m_{ij}\) is the number of endpoints for the same cell corresponding to the fine particles concentrations higher than a setting criterion value and \(n_{ij}\) is the total number of endpoints in the grid cell.

In this study, the PM\(_{2.5}\) criterion value was set to 75 \(\mu g/m^3\), the 24-hour NAAQS concentration limit. All hourly endpoints from the back-ward trajectories were classified into \(0.5^\circ \times 0.5^\circ\) latitude and longitude grid cells.

To reduce the effect of small values of \(n_{ij}\), the PSCF values were multiplied by a weighting function. The weighting function was based on the average number of trajectory endpoints in each grid cell (Equation (2)):

$$w = \begin{cases} 
1.0 & 3n_{ave} < n_{ij} \\
0.7 & 1.5n_{ave} < n_{ij} \leq 3n_{ave} \\
0.4 & n_{ave} < n_{ij} \leq 1.5n_{ave} \\
0.2 & 0 < n_{ij} \leq n_{ave}
\end{cases}$$

(2)

where \(n_{ave}\) is the average number of trajectories points of all grid cells which contain at least one trajectory and \(n_{ij}\) is the number of the included trajectory points in the \((i,j)\) cell. In this regard, the
PSCF method is commonly used for identifying likely regional sources. However, the limitation of PSCF model is that two grid cells can have the same PSCF value when sample concentrations at the receptor site are either only slightly higher than or much higher than the criterion. Therefore, it's hard for the PSCF method to identify the strong sources from moderate sources from strong ones.

**Results and Discussion**

Studies indicate that the PM$_{2.5}$ pollution can not only be caused by the local sources, but also caused by the regional transport. According to the recent studies, both the local sources and the regional transport would affect the air quality of city\[^{5-6}\]. Seventy-two-hour back trajectories were applied to understand the relationship between hourly PM$_{2.5}$ concentrations and transport pathway of the air masses in Panjin. The optimum number of clusters was established by analyzing the change in the total spatial variance. The results are shown in Figure 2 and Table 1. For the period 1 (Figure 2(a)), the back-trajectories were classified into 4 clusters, and cluster 1, 2, 3 and 4 comprises 47.92%, 18.75%, 10.42% and 22.92% of the back-trajectories, respectively. As seen in Table 1, all air masses backward trajectories of four clusters showed relative short, indicating the wind speed was slow and pollutants were able to accumulate during this haze episode. Cluster 1 which originated from the northern Inner Mongolia across the Hebei province and Beijing before reaching the Liaoning province. As illustrated in Table 1, the mean hourly PM$_{2.5}$ concentrations were 107.06 μg/m$^3$. Fourteen of the twenty-three air trajectories exceeded the criterion of PM$_{2.5}$ with the polluted mean PM$_{2.5}$ concentration of 134.5 μg/m$^3$, which was the highest concentration in all clusters during period 1. The back-trajectories of cluster 2 came from Shandong province, travelled to Jiangsu province first and then came back to Shandong province, passed through the Bohai sea. The number of back-trajectories was nine and all the back-trajectories reached the criterion with the value of 98.33 μg/m$^3$. Cluster 3 began from Hebei province, however both the trajectories number and polluted mean PM$_{2.5}$ concentration were the smallest of all the cluster. Cluster 4 started from southeastern of Inner Mongolia, crossed the Hebei province and Shandong province. All the eleven back-trajectories passed the criterion of PM$_{2.5}$.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Num</th>
<th>mean_value (μg/m$^3$)</th>
<th>Stdev</th>
<th>P_Mun</th>
<th>P_value (μg/m$^3$)</th>
<th>P_stdev</th>
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<td>134.5</td>
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<td>9</td>
<td>98.33</td>
<td>2.97</td>
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<td>98.33</td>
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<td>124.94</td>
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<td>163.06</td>
<td>101.23</td>
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<td>51.97</td>
<td>10</td>
<td>174.5</td>
<td>51.97</td>
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</tbody>
</table>

For the period 2 (Figure 2(b)) lasted from November 6 to 14, the back-trajectories also could be separated into 4 clusters. Cluster 1 accounted for 12.96% air masses with the mean hourly PM$_{2.5}$ concentrations of 163.06 μg/m$^3$ and twenty-four of all the trajectories were polluted. The air masses, coming from Russia, travelling through Heilongjiang province, Jilin province and then arrived the Panjin. The trajectories showed the longest pattern and highest wind speed of all the clusters, reflecting regional transport. Cluster 2 accounted for 23.15% air masses with the mean hourly PM$_{2.5}$ concentrations of 153.1 μg/m$^3$. The air masses started at the Ningxia Hui Autonomous Region, passing over the Shanxi province and Beijing-Tianjin-Hebei region prior to arriving the Panjin.
Cluster 3 accounted for 9.72% air masses with the mean hourly PM$_{2.5}$ concentration of 147.65 $\mu$g/m$^3$ and all the trajectories were polluted. The air masses back-trajectories showed that the Sea of Japan Region was the origin. However the difference is that only two of all the twelve air trajectories exceeded the criterion with the lowest polluted mean PM$_{2.5}$ concentration of 80.85 $\mu$g/m$^3$, suggesting the air masses of cluster 3 were not the main pollution masses. Cluster 4 accounted for the remaining 54.17% air masses with the mean hourly PM$_{2.5}$ concentration of 185.39 $\mu$g/m$^3$, suggesting the air masses of cluster 4 were the main pollution masses. The air masses moved from the northeastern Inner Mongolia. One hundred and six of all the one hundred and seventeen back-trajectories passed the criterion with the highest polluted PM$_{2.5}$ concentration. According to the results, this haze episode of Panjin were mainly affected by the regional transport, while air masses came from Inner Mongolia.

For the period 3 (Figure 2(c)), the back-trajectories were divided into 3 clusters which account for 23.91%, 54.35% and 21.74% the back-trajectories, respectively. The spatial patterns of cluster were all from Mongolia, indicating that the air masses from Mongolia was the source of this haze episode, thereinto, all the air masses back-trajectories of cluster 2 and cluster 3 exceeded the criterion of PM$_{2.5}$ concentration.

Figure 2. Results of the back-trajectory cluster analysis for the three haze episodes.

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In our study, different haze episodes show different air transport paths, however, Mongolia and Inter Mongolia mostly affects the air quality of Panjin and the air pollution in Panjin was mostly caused by the regional transport. Studies also indicated meteorological factors such as the low wind speed and high relative humidity (RH) can promote the formation of secondary inorganic ions and accelerate hygroscopic growth.

**Summary**

The back-trajectories and PSCF analysis of three haze episodes show different air transport paths, however, Inter Mongolia and Liaoning province mostly affects the air quality of Panjin. The results obtained from this study are expected to be useful for enlarging degree of pollution prevention and treatment in Inter Mongolia and Liaoning province to improve air quality at Panjin.

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**References**


