Analysis of PM2.5 Transport Routes and Potential Sources of Qingdao in Winter

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Abstract: Combined the mass concentration of PM2.5 in Qingdao region, with TrajStat software and the data from global assimilation system, getting the result of airflow backwards trajectory altered every 24-hour in November 2019 in Qingdao. The chief factors influenced the mass concentration of PM2.5 in Qingdao are wind speed and humidity. With the condition of lower wind speed and higher humidity causing heavier pollution. The airflow clusters in Qingdao can be classified into six types by using TrajStat software, and researchers made a series of study over each airflow direction. They also found that the particle concentration in Qingdao was mainly disrupted by the emission emitted within Shandong province, while getting a slight possibility of disruption from remote areas.

1. Introduction

The atmospheric particle is the chief pollutant which disrupts the air quality in our most of cities. Moreover, it has a profound disruption to the environment, the climate and human health\(^{[1]}\). A mass of particles below PM2.5, this is called -The Airborne Fine Particle, this kind of particle has a so vast surface that it can be prone to get some harmful matters on its surface. It triggers various diseases to human beings in a way by inhaling it into blood and alveolus. Therefore, it becomes the hot topic when it comes to the channel and the origin of the PM2.5\(^{[2-3]}\).

Study found that the air pollution is not only affected by the emission from local residents, but also affected by the remote transmission. Ren Chuabin\(^{[4]}\) took the mixture of quality , intensity, ground-bases measurements of PM2.5 to analyze the spacious features of the different transmission ways and how much of PM2.5 they contribute to Beijing city, and made use of the analyzing ways of PSCF and CWT to reveal that PM2.5 lies in potential regions in different seasons and its contribution features during the study period. Hetao\(^{[5]}\) took the same way as Ren did to analyze the different sources of pollution in Changzhou, in Jiansu province. He found that the PM2.5 is the principal pollutant, and Changzhou remains dominant compared with the rest part of Yangtze River Delta Region, but one question can not be ignored is the contribution of long-distance pollution transportation. Wanglu\(^{[6]}\) who analyzed the conveying path and potential source of two components about PM2.5 to the apex of Tai mountain, he found that airflow came from different directions in winter and summer made an obvious difference to the PM2.5 component and potential source distribution at the apex. And its pollutant regions mostly lies in Jiing, Liaocheng of Shandong province, and its near provinces, such as Shanxi, Hebei, Henan. Duan Shiguang\(^{[7]}\) analyzed that the particle intensity disrupted by weather conditions. He found that the main weather factors to cause sever particle pollution are slow speed of wind, high humidity, slight rainfall. and also analyzed the
PM2.5 potential source in winter of Zhengzhou and PM2.5 concentration contributed by and from different potential sources. And its potential sources mainly located in some northern parts which have conveying paths, such as Beijing Tianjin Hebei. Besides, adjacent provinces like Shanxi, Hubei, and Anhui, contributed a great deal of pollution and largely lifted the level of PM2.5 in Zhengzhou. From these studies, we have learned that Qingdao has become a target city for us to continuously observe the mass concentration of PM2.5 in spring. We have summarized the change rule of mass concentration, the transport path of PM2.5, and how the mass concentration of PM2.5 is affected by the long-distance transport. The conclusion can provide valuable reference for Qingdao municipal government to take air pollution control measures

2. Materials and measurements

2.1 Data sources
The data I would like to use about the mass concentration of PM2.5 came from Huangdao region in Qingdao city. The record was taken by hourly in November of 2020. the data of air trajectory supported by GDSA of NCEP. In this study, the starting point of air trajectory in the air, 500 meters above the ground. 24-hour of air mass backwards trajectory means 1 hour of time revolution. Backwards trajectory was simulated by adopting Meteoinfo software of HYSOLIT pattern and the cluster computation of airflow trajectory provided by the rule of Euclidean Distance of TrajStat software in which in a way of judging the quality of classification by using the formulation of total spatial variance. Ultimately, the number of track clusters as the final decision is the classification result which showed before the second rapid increase of TSV.

2.2 Potential source contribution function
PSCF is the function of conditional probability that backwards trajectory can describe the locations of potential pollutant areas. The potential source area can be known for sure by the combination of backwards trajectory and certain factor value. Based on the spatial grid computing, PSCF is a ratio that formed by the pollutant airflow trajectory endpoint number over the all airflow trajectory endpoint number when they pass the same grid in the targeted area. The formulation is as below.

\[
PSCF_{ij} = \frac{n_{ij}}{n_{ij}} W(n_{ij})
\]

The ratio of PSCF fluctuated as the distance between the grid point and observation point, as well as the time for airflow to remain in the grid. Therefore, so as to reduce the error, it is necessary to cite Weight function. The formulation is following.

\[
W(n_{ij}) = \begin{cases} 
1.00 & 0 \leq n_{ij} \\
0.70 & 80 \leq n_{ij} \leq 80 \\
0.42 & 20 \leq n_{ij} \leq 20 \\
0.05 & n_{ij} \leq 10
\end{cases}
\]

The higher of the ratio of PSCF means the more possibility of the grid affects the concentration of observation point. Otherwise, less possibility. The potential source region is the area where shows the high ratio of PSCF.

2.3 Concentration -weighted trajectory)
The ratio of PSCF shows only the portion of pollutant trajectory number in the grid. So neither it can present the pollution contribution from pollutant trajectory to targeted gird, nor distinguish the effect caused by the grid point to the pollutant concentration of observation point. So make use of CWT to display the pollution concentration of different trajectories. So the ration of pollution in the potential source areas could be simulated the CWT. The formulation of CWT ran beneath. Weight function applied to PSCF, applied to CWT as well.
3. Result discussion

3.1 Weather situation in observation period and the analysis of trajectory clustering.

From the first day to the last day of November in 2019, except the occasion of rainy weather, meteorological condition at observation point was relatively stable. Throughout the whole observation period, the daily temperature showed the consistent tendency. The highest temperature of a day appeared at 2Pm with 20 Celsius degrees, while the lowest temperature appeared at 5Am with -0.8 Celsius degree. Averaged 10.8 Celsius degrees. The maximum of relative humidity appeared at 20Pm and 5Am respectively. The daytime went alone with lower relative humidity, averaged 60.08%. The wind speed in observation period ranging from 0--12m/s ,averaged 3.77m/s.But the wind direction was complex and various in the study period , the atmospheric pressure from 20th -21st was below the standard atmospheric pressure, the atmospheric pressures of the rest of days were all above the standard. 103924.79Pa, which was the peak of atmospheric pressure in the whole month, showed up from 3rd to 4th. The weather condition of the whole November, the fog or smog took account for 42.5%, once it happened, the sky was invisible. With the averaged visibility of 17.4km, the maximum visibility of 3okm, and the minimum visibility of 0.5km.

720 pieces of backwards trajectories have been made cluster computing with using Trajstat software during the observation period, the result of TSV showed that 6 main channels of transmission have been procured (See Figure 1), the trajectory 1 originated from the juncture of Nei Monggol and Liaoning , reached Qingdao via Bohai bay, the trajectory 2 came from southeast Shandong province, where nearby the sea, with shorter transmission distance, the trajectory 3 displayed with slight difference with trajectory 1 ,but came from Nei Monggol to Qingdao,via mostly parts of Hebei and Shandong. The number four took its rise from at west part of Shandong, and traversed within Shandong to Qingdao. Nei Monggol, again, but this time, became the home for number 5 which originated from the east part of Nei Monggol moved towards Liaoning, then Bohai bay, finally Qingdao, alone with southeast directions. Southeast coastal area was the home for trajectory 6, moved along with Jiangsu costal line to arrive Qingdao.

![Figure 1. Trajectory clustering figure.](image)

Backwards trajectory routine and direction represent the way of airflow towards observation station, and its length represents airflow speed, the shorter the trajectory is, the slower the airflow moves, otherwise, the longer the trajectory is, the faster the airflow moves. Weather condition remained
relatively stable during the observation period, pollutants were prone to pile up under the weather condition of slow wind speed, clustering 4 came from Shandong with slowest speed compared with others, but its frequency of occurrence owned the largest rate, which was 30.42%.

Affected by the northwest monsoon in winter, northwest airflow trajectory took a relatively high rate, among others, such as: clustering 1, 3, 5 all directly northwest direction, they took account for 15.83%, 14.03%, 11.67% respectively, there were two ones from Shanghai: clustering 2 and 6, with each’s frequency of occurrence 17.08%, 10.09% respectively.

3.2 Characteristics of PM2.5 mass concentration
PM2.5 mass concentration ranging from 2-150ug/m3 measured in November, averaged 33.89ug/m3, the relatively high level of PM mass concentration took place three times in November, 7th and 9th nighttime and in the small hours of next day. The relatively low level of PM 2.5 mass concentration started from the 21st, lasting for 5 days, ended at 7Am on 26th. The study showed that PM 2.5 mass concentration under 50ug/m3, took the largest rate in November, which was 76.67%. 17.78%, the middle rate in which the PM mass concentration between 51-100 ug/m3, 5.55% only, the smallest rate, was above 100ug/m3 throughout November.

In the following table, the meteorological elements of different background clusters in different seasons counted with PM2.5 mass concentration.

| Trajectory | Clustering 1 | Clustering 2 | Clustering 3 | Clustering 4 | Clustering 5 | Clustering 6 |
|------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Frequency of occurrence | 15.83% | 17.08% | 14.03% | 30.28% | 11.67% | 11.11% |
| Mean temperature | 9.76 | 13.11 | 10.26 | 10.76 | 5.71 | 16.17 |
| Visibility | 18.73 | 21.28 | 13.72 | 14.57 | 20.81 | 13.38 |
| Relative humidity | 57.65 | 65.50 | 56.13 | 55.32 | 58.47 | 78.53 |
| Wind speed | 4.18 | 2.38 | 6.25 | 2.68 | 5.67 | 3.32 |
| Mean pressure | 102704.55 | 102496.29 | 101948.28 | 102389.70 | 103155.07 | 101943.90 |
| Mass concentration | 32.93 | 27.82 | 36.99 | 42.16 | 34.80 | 16.07 |

Airflow 2 and 6 all came from southeast offshore, they have some feature in common, such as: clean air quality, high humidity, high temperature, low mass concentration of PM2.5. with these conditions, the pollutants had trouble in piling up. Airflow 1, 3, 4 and 5 all directly came from inland with low humidity and temperature and high mass concentration of PM2.5, airflow 1, 3, 5, having similarity in trajectory direction and PM mass concentration. The last one to report, airflow 4, took its rise from Shandong inland, with the condition of high frequency of occurrence, slow speed, the pollutants was conducive to accumulate, so the airflow 4 had highest mass concentration of PM2.5.

3.3 Potential Source Distribution
Analyzing the potential source of PM2.5 with PSCF and CTV, to confirm the potential source distribution of PM 2.5 in winter of Qingdao city. The air flow coverage area is grided and the grid size is 0.3°x0.3. The analysis of potential source contribution factors showed that PM2.5 in autumn and winter of Qingdao. Was influenced mainly from the Northeast of Qingdao and the West of Shandong. The high rate of PSC was distributed in Shandong area, Just west of Qingdao. Through which air mass 4 flowed. This was related to the high frequency of occurrence of air mass 4 trajectory. And the slow speed of air mass 4 was not conducive to the diffusion of pollutants.
The airflow from the southeast also had a high rate distribution, but it is relatively close to Qingdao, the main impact was local emissions, impacted slightly by remote transmissions. The influence of airflow from other sources on Qingdao areas was not significant, the results of CWT and PSCF showed that the source area was similar, and areas nearby Qingdao hit by a great deal of influence. On this very note, this suggested the PM2.5 mass concentration in Qingdao area was mainly affected by the local emission and its neighboring areas, while the influence of long-distance transmission on Qingdao was faint.

4. Conclusion

In winter, the average mass concentration of PM2.5 in Qingdao is 33.89ug/m3, low wind speed and humidity often lead to high concentration of particles.

In winter, the airflow comes from the northwest region has the dominant rate, which is 41.53%, and the one comes from Shandong inland accounts for about 30.28%, while the rate of the one comes from sea is slightly lower that last one, which is 28.9%, among them, the second one has the most remarkable influence on Qingdao.

About the PM2.5 in winter of Qingdao, the results were similar as PSCF and CWT showed, the high rate appeared in Shandong, right to the west of Qingdao, and southeast sea area nearby Qingdao, the pollutants in Qingdao were more affected by local emissions, but less by external transmissions.

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