Computer Mathematical Statistics and Comparative Analysis of Meteorological Conditions in the Bohai Rim Region through Big Data Digitization

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Abstract. Based on the data of environmental monitoring stations and meteorological stations in typical city in the Bohai Rim region in June 2021 and June 2020. The air quality in June 2021 was better than that in the same period in 2020. Ozone (O₃) was the primary pollutant in June 2021 and June 2020. The overall meteorological conditions in May 2021 were relatively favorable. In June 2021, the number of light wind days and wind speed had no significant impact on air quality compared with the same period last year. The dominant wind direction in June 2021 was southeast wind, which was not conducive to the increase of ozone concentration compared with the southwest wind frequency in the same period in 2020; the relative humidity in June 2021 was slightly higher year-on-year, which was slightly conducive to the hygroscopic growth of pollution; the static stability index in June 2021 was lower year-on-year, and the weather conditions for comprehensive pollution diffusion were preferred year-on-year; the height of the mixed layer in June 2021 was lower year-on-year, the vertical diffusion weather conditions were deviated year-on-year; the average temperature, sunshine hours and total radiation in June 2021 were all low, which was not conducive to the generation of ozone.

Keywords: Pollution characteristics, Meteorological conditions, Comparative analysis, Typical city in the Bohai Rim region

1. Introduction

Ozone (O₃) was mainly distributed in the stratospheric atmosphere, and the content of O₃ in the troposphere was very small [1]. In recent years, the increase of O₃ concentration in the troposphere had attracted more and more attention. O₃ was mainly generated by photochemical reactions of nitrogen oxides (NOx), carbon monoxide (CO) and volatile organic compounds (VOCs) under sunlight [2]. O₃ could stimulate the human respiratory system, destroy the immune system, cause inflammation and respiratory diseases, etc., and seriously endanger human health [3-4]. O₃ pollution in the Beijing-Tianjin-Hebei region was mostly "single-peak", with peaks concentrated in May-July [5]. The diurnal
variation of O₃ was a single-peak distribution, with the highest concentration in the afternoon [6]. Meteorological conditions affected the generation, transmission and dissipation of O₃ and its precursors, and had a greater impact on the changes in tropospheric O₃ concentration. On the whole, higher temperature, combined with lower relative humidity, wind speed and favorable wind direction was conducive to the accumulation of O₃ pollution [7]. In the Bohai Rim region, the peak ozone concentration had increased year by year in recent years, heavy pollution days had emerged from scratch, and the overall trend was on the rise. This article would compare and analyze the characteristics of air pollution in typical city in the Bohai Rim region in June 2021 and June 2020, as well as the relationship with meteorological elements, so as to provide certain technical support for ozone pollution forecasting and early warning.

2. Data sources and methods
Using the concentration monitoring data of six pollutants (PM₂.₅, PM₁₀, O₃, SO₂, NO₂, CO) at Qinhuangdao Environmental Monitoring Center in June 2021 and June 2020, Meteorological data were wind direction and wind speed, relative humidity, 2m temperature and total radiation, Stable weather index(SWI), Height of mixed layer at the Qinhuangdao.

3. Results and discussion
3.1. Comparative analysis of air quality in June 2020 and June 2021
3.1.1. Comparative analysis of overall air quality. In June 2021, the city's comprehensive air quality index (average of 5 national control points, the same below) was 3.28 (Fig.1) , a decrease of 18.2% compared with the same period in 2020 (4.01); fine particulate matter (PM₂.₅) was 24μg/m³, which was the same as 2020 In the same period of the year (24μg/m³), the concentration of sulfur dioxide (SO₂), nitrogen dioxide (NO₂), carbon monoxide (CO), ozone (O₃), and inhalable particulate matter (PM₁₀) were all down 16.7%, 17.2%, 11.1. %, 29.8%, 18.5%.

Figure 1. Comparison of the average concentration of six pollutants of Qinhuangdao city in June 2020 and June 2021 (the unit of CO concentration 0.1mg/m³)

3.1.2. Comparative analysis of the number of days at all levels. In June 2021, the city’s average number of compliance days was 27 days, accounting for 90% of the effective monitoring days in the entire month, an increase of 9 days compared with the same period in 2020 (18 days, 60%). The city had 5 days of excellent, 22 days of good, and 3 days of mild pollution. Compared with the same period in 2020: the number of high-grade days increased by 2 days, the number of good-grade days increased by 7 days, light pollution decreased by 4 days, moderate pollution decreased by 4 days, and heavy pollution decreased by 1 day.
3.1.3. The relationship between ozone and fine particulate matter (PM2.5). Near-ground ozone was mainly generated by photochemical reactions, and luminous flux and radiation intensity had a direct impact on the production of ozone. The lower concentration of particulate matter in the summer air was conducive to the penetration of ultraviolet rays, thereby strengthening photochemical reaction. A higher ozone concentration also marked an increase in atmospheric oxidizability, which in turn would promote the generation of secondary fine particulate matter. Therefore, the later stage of ozone pollution was often accompanied by an increase in the concentration of fine particles. The high ozone process from June 5th to 8th and 11th to 12th of this month (Fig.2) showed that after a period of time after the ozone peak, the concentration of fine particles gradually increased. With the end of the pollution process, the concentration of these two pollutants decreased.

![Figure 2. Time series of daily changes of O3 and PM2.5 of Qinhuangdao city in June 2020 and June 2021](image)

3.2. Comparative analysis of meteorological conditions

3.2.1. Analysis of the high and low altitude situation. Through the 500hPa average height field in June 2021 (Fig.3 left), it could be seen that the 500hPa average height field in June 2021 was that the middle and high latitudes of Asia were composed of two troughs and one ridge, and the Qinhuangdao area was controlled by the westerly trough. There were more disturbances in the upper and lower layers, with more precipitation, more cloud cover, and weaker radiation, which was not conducive to the generation and development of ozone. From the average sea level pressure field in June 2021 (Fig.3 right), it could be seen that the Qinhuangdao area was mainly controlled by the center of low pressure, low pressure inverted troughs, and more precipitation, which was conducive to the removal and sedimentation of pollutants.

![Figure 3. The 500hPa average height field and anomaly field in June 2020(left) and June 2021(right)](image)
3.2.2. Wind direction and speed. The number of light wind days in June 2021 (average daily wind speed <2 m/s) was 30 days (Table 1), which was one more day than June 2020. The number of light wind days was basically the same, and there was no significant impact on the horizontal diffusion conditions of pollutants. The average wind speed in Qinhuangdao in June 2021 was 1.30 m/s, which was 0.08 m/s lower than that of 1.38 m/s in June 2020, and had no significant impact on the horizontal diffusion of pollutants. Based on a comprehensive analysis of the number of days with low winds and the average wind speed, the pollutant level diffusion conditions in Qinhuangdao City in June 2021 had no significant impact year-on-year.

| Month | The number of light wind days (day) | average wind speed (m/s) |
|-------|-----------------------------------|-------------------------|
| June-20 | 29                                | 1.38                    |
| June-21 | 30                                | 1.30                    |

From the wind frequency rose chart in June 2021 (Fig. 4 left), the maximum wind direction was southeast wind, and the wind direction frequency was 16.94%. The wind frequency rose chart in June 2020 (Fig. 4 right) was the maximum wind direction, southwest wind, the wind direction frequency was 14.86%. The frequency of the southeast wind direction in June 2021 was smaller than the frequency of the southwest wind direction in the same period in 2020, which had a smaller effect on the increase in temperature and humidity conditions, which was not conducive to the increase of ozone concentration.

3.2.3. Relative humidity conditions. According to research, the average concentration of ozone was the highest in the range of 65%-75% relative humidity, and there was a positive correlation between the two in the low humidity range, and a negative relationship in the high humidity range. The relative humidity in June 2021 was 79.8% (Table 2), which was 3.4% higher than that of 76.4% in June 2020. The relative humidity was higher, which was conducive to the hygroscopic growth of pollution, but was disadvantageous to the dilution and diffusion of pollutants.

3.2.4. Temperature and radiation conditions. The average temperature in June 2021 was 21.2°C, which was 1.3°C lower than 22.5°C in the same period in 2020 (Table 2). The total sunshine hours in June 2021 was 181.4h, which was 54.8 hours less than the 236.2h in the same period in 2020. The total radiation exposure in June 2021 was 550.6MJ/m², which was 757.8MJ/m² less than the 1308.4MJ/m² in the same
period in 2020. Higher temperature, longer sunshine hours and higher total radiation are conducive to the generation of ozone. The average temperature, sunshine hours and total radiation in June 2021 were significantly lower than those of the same period in 2020, which was not conducive to ozone’s generation.

3.2.5. Precipitation. The magnitude of precipitation and the nature of precipitation would have a significant impact on ozone concentration. No or little rain for consecutive days was a necessary condition for the occurrence of ozone pollution events. The total precipitation in June 2021 was 89.3mm (Table 2), which was 80.8 more than 8.5mm in the same period in 2020. mm, precipitation was too much, which was conducive to the removal of pollutants in the air, and was not conducive to the accumulation of ozone precursors and the occurrence of various photochemical reactions in the atmosphere.

Table 2. The conditions of temperature and humidity in June 2020 and June 2021

| Month   | Relative humidity (%) | Air temperature (°C) | Total sunshine hours (h) | Total radiation (MJ/m²) | Precipitation (mm) |
|---------|-----------------------|----------------------|--------------------------|-------------------------|-------------------|
| June-20 | 76.4                  | 22.5                 | 236.2                    | 1308.4                  | 8.5               |
| June-21 | 79.8                  | 21.2                 | 181.4                    | 550.6                   | 89.3              |

3.2.6. Static weather index. The static weather index integrated a number of meteorological elements to characterize the ability of meteorological conditions to diffuse atmospheric pollutants. The larger the value, the less conducive to the diffusion of pollutants. The static stability index in June 2021 was 9.50 (Fig. 5), which was 0.86 lower than 10.36 in June 2020, and the static stability index was lower year-on-year. Therefore, the weather conditions for comprehensive pollution diffusion were preferred year-on-year.

3.2.7. Height of mixed layer. The height of the mixed layer characterizes the vertical diffusion capacity of atmospheric pollutants by meteorological conditions. The larger the value, the more conducive to the diffusion of pollutants. The height of the mixed layer in June 2021 was 589.0m (Fig.5), which was 63.7m lower than 652.7m in June 2020. Therefore, the meteorological conditions for the vertical diffusion of pollutants deviated from the comparison.

Figure 5. The distribution of static stability index and the mixed layer of Qinhuangdao in June 2020 and June 2021
4. Conclusion
The air quality in June 2021 was better than that in the same period in 2020. Ozone (O₃) was the primary pollutant in June 2021 and June 2020. In June 2021. The number of light wind days and wind speed had no significant impact on air quality compared with the same period last year. The dominant wind direction in June 2021 was southeast wind, which was not conducive to the increase of ozone concentration compared with the southwest wind frequency in the same period in 2020; the relative humidity in June 2021 was slightly higher year-on-year, which was slightly conducive to the hygroscopic growth of pollution; the static stability index in June 2021 was lower year-on-year, and the weather conditions for comprehensive pollution diffusion were preferred year-on-year; the height of the mixed layer in June 2021 was lower year-on-year, the vertical diffusion weather conditions were deviated year-on-year; the average temperature, sunshine hours and total radiation in June 2021 were all low, which was not conducive to the generation of ozone.

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