The Air Quality of Xi'an City Studied by Hurst Index

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Abstract. Air quality is related to people's health, and in today's rapid development of industry, the research of air quality is more and more important. The author selected two pollutants that can represent air quality, sulfur dioxide and particulate matter 10, and used the R/S analysis method in the time series to study the monthly data of these two pollutants in Xi City from August 2018 to August 2022, and found that the regular changes of these two pollutant indices on the time scale, that is, the natural year is generally used as a cycle. The previous pollutant index has a continuous impact on the future pollutant index. Finally, based on the unique geographical location of Xi in the Guanzhong Plain, the possible reasons for the change in pollutant index were speculated. It is hoped that this article will be helpful for the prevention and control of air quality in Xi'an in the future.

Keywords: Xi'an city, sulfur dioxide, particulate matter 10, Hurst index, urban air quality.

1. Introduction

The development of human society has neglected the protection of the natural environment, which has led to many existing environmental problems, such as global warming, the disappearance of tropical rainforests, and the decline of environmental quality. Among them, environmental quality is closely related to human life, and every breath is inseparable from it, people have gradually realized the importance of environmental quality. As the author's hometown, to better govern and improve its environment and climate, this paper uses scientific statistical means to better understand its laws and analyze the possible causes, so that the governors have a convincing reason to prescribe the right medicine and make the blue sky of Xi'an, which is now very clear, more beautiful.

2. The air quality of Xi'an city studied by Hurst index

2.1. Selective Statistical Method

The evolution of urban air quality is a complex process of open and dissipative atmospheric giant systems under the stress of anthropogenic pollution. The formation and evolution of high pollution are not only affected by anthropogenic emissions but also by microscopic atmospheric physicochemical, meteorological, topographic, and other mechanisms, which are manifested as macroscopic and holistic system dynamics.

In this way, it can be inferred that the air quality status in the past time in the atmosphere will also have a certain continuous effect on the present and even the long-term future to some extent, resulting in a biased random walk in the evolutionary time series of urban air quality. This is reflected in the fact that the evolution of air pollution systems has a certain "persistent memory" or long-term correlation in time and space. The air quality of cities in the future will be affected by the lasting effects of the air quality that precedes it. By changing the time scale of the study, analyzing the law of the change of statistical characteristics of urban air quality, and studying the long-term sustainability of air quality evolution, the predictability of urban air quality can be obtained, and a reliable atmospheric environment prediction method can be established on this basis.

This paper will model the relationship between pollutant emissions and air quality through a time-series analysis method, and use the HURST index size to predict future air quality, which can help us formulate environmental protection policies and measures to improve quality of life [1, 2].

2.2. Specific Research Process

The paper first found a dataset of the indices of sulfur dioxide (one of the six major air pollutants, classified as a Group 3 carcinogen by the World Health Organization in 2017) and particulate matter 10 (one of the official air quality standards, which refers to pollutants with a diameter of 10 microns or less in aerodynamics, which has a significant impact on human health and atmospheric visibility) in Xi'an, Shaanxi Province, China, for four years from September 2018 to August 2022. We know from the above that the four-year AQI is a system with HURST statistical properties, because the air quality of a city over several years is the result of a long series of interconnected events, and today's air quality will affect the future, and the air quality of the past will affect the present. I will use the R/S analysis method, i.e., the rescaling range analysis, import the data, and use a computer program to create a model plot, and the slope of the straight-line part of the graph is the hurst index. This paper first made a general graph of the sulfur dioxide air index over four years and found that as shown in figure 1, according to the law of slope variation, the hurst index has four consecutive intervals of significant changes. As shown in figure 2, the first interval is from September 2018 to August 2019 and corresponds to the hurst index of H1=0.8467. As shown in figure 3, the second interval is from September 2019 to August 2020 and the corresponding hurst index is H2=0.8659. As shown in figure 4, the third interval is from September 2020 to August 2021 and the corresponding hurst index is H3=0.9090, and as shown in figure 5 the fourth interval is from September 2021 to August 2022 and corresponds to the hurst the index is H4 = 0.7101.

Next, a general map of the particulate matter 10 air index over four years is drawn, and it is found that as shown in figure 6, according to the similar law of linear changes, the graph can be divided into three parts, which have a large slope and a small slope first. The hurst index values of the interval with a large slope and the interval with a small slope in these three parts correspond one-to-one and are the same size. Therefore, as shown in figure 7, we choose the first part and calculate the hurst index corresponding to the interval with a large slope is H1=0.8785, and as shown in figure 8, the hurst index corresponding to the interval with a small slope is H2=04848.

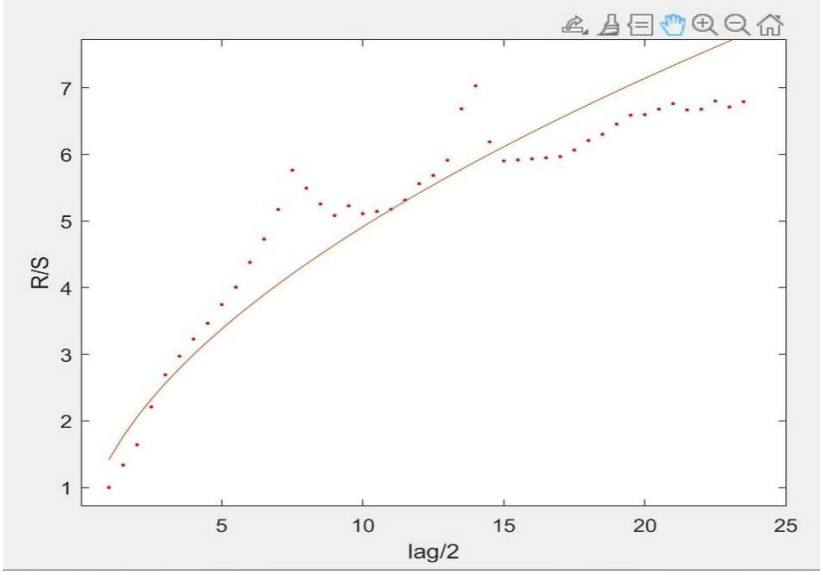

Figure 1. A general graph of the sulfur dioxide air index over four years

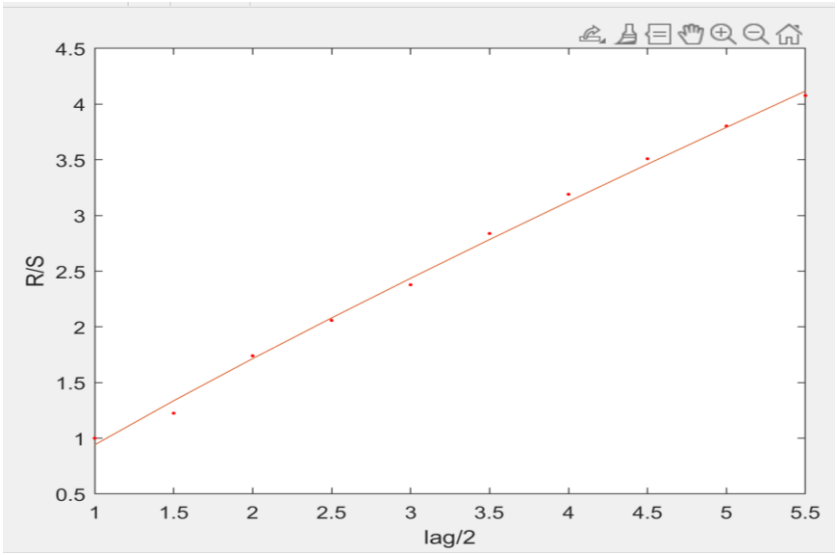

Figure 2. Hurst index for sulfur dioxide from September 2018 to August 2019

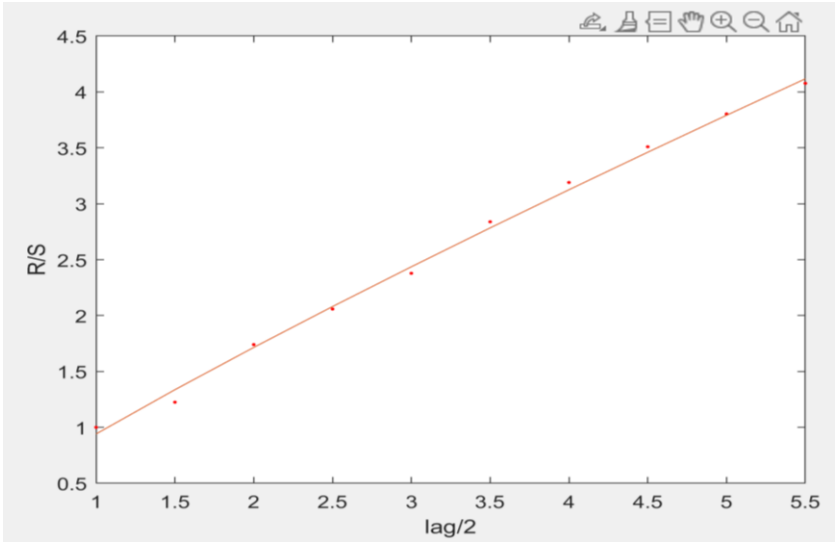

Figure 3. Hurst index for sulfur dioxide from September 2019 to August 2020

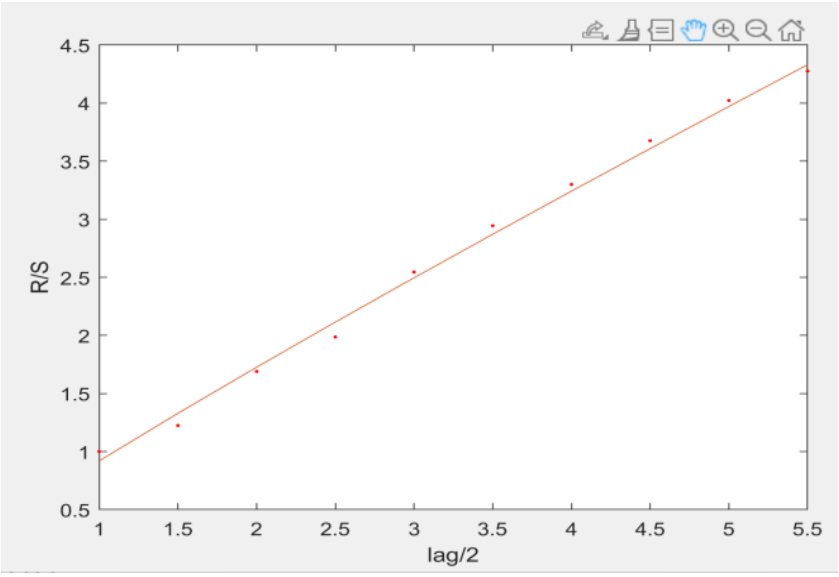

Figure 4. Hurst index for sulfur dioxide from September 2020 to August 2021

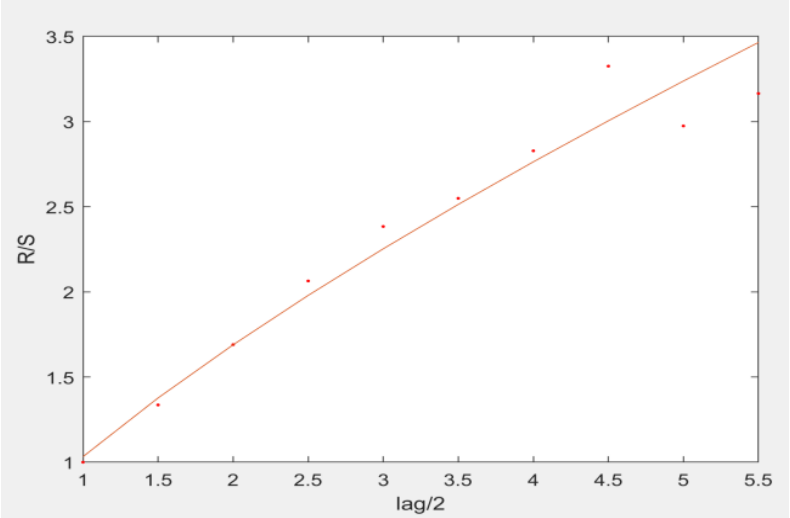

Figure 5. Hurst index for sulfur dioxide from September 2021 to August 2022

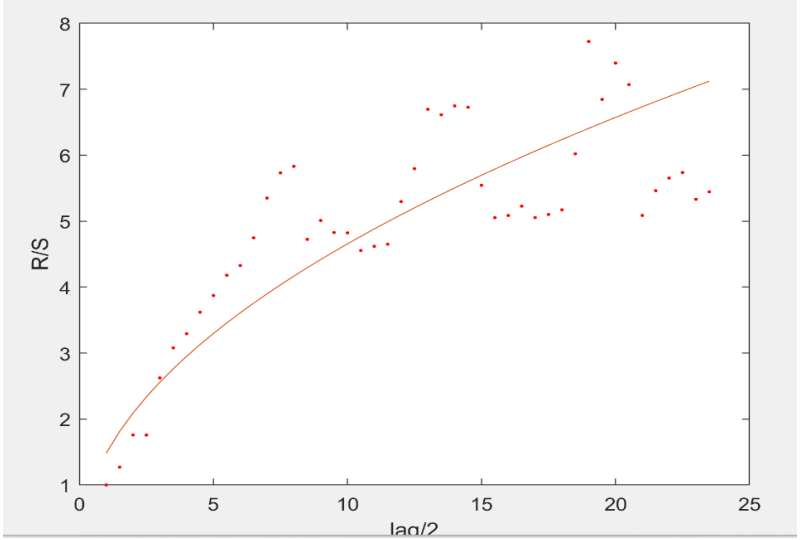

Figure 6. A general map of the particulate matter 10 air index over four years

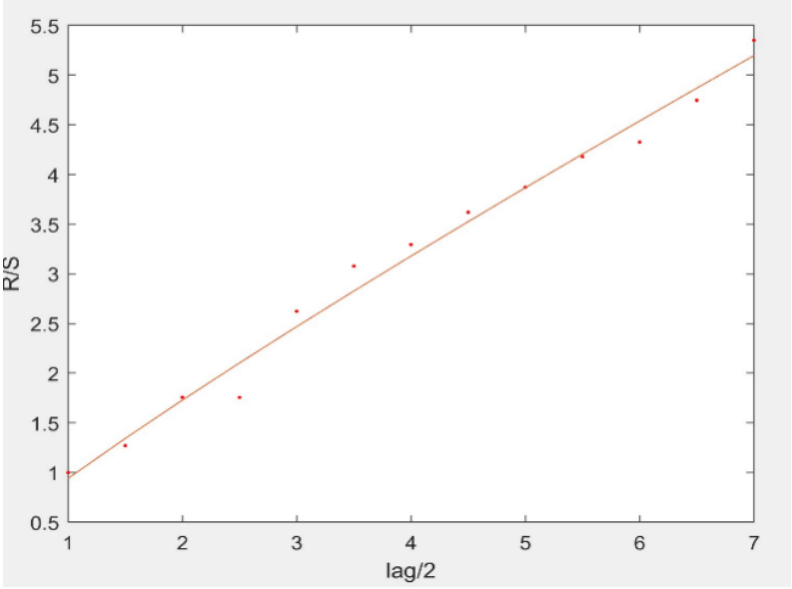

Figure 7. The hurst index corresponding to the interval with a large slope

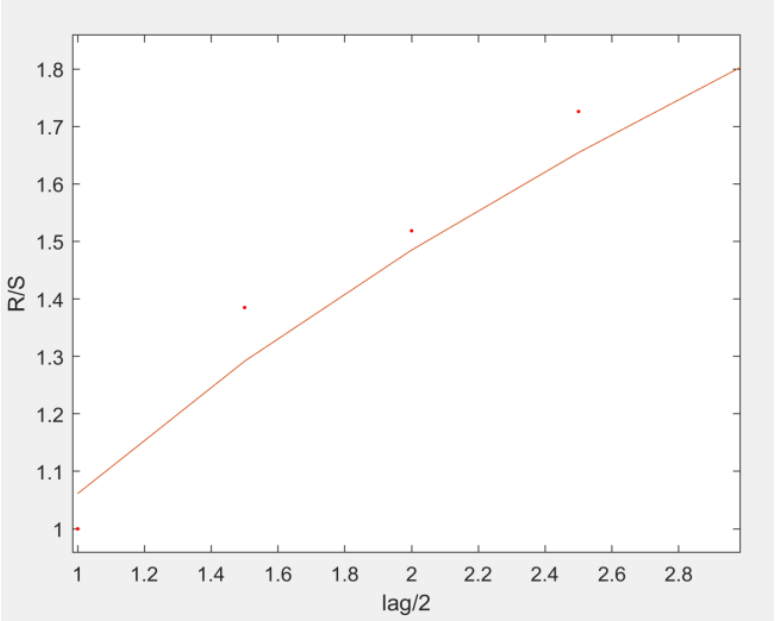

Figure 8. The hurst index corresponding to the interval with a small slope

The fitting of the time series data of sulfur dioxide and particulate matter 10 pollutants has several different but similar intervals, that is, the corresponding time of the boundary point is one year, reflecting the general influence of the natural year on urban pollutants.

For the pollution index of sulfur dioxide, the Hurst index is H1≈0.84 in the first interval; And when over a year, the Hurst index. This relation H3>H2>H1>H4>0.5 is quite unexpected, which indicates that the sulfur dioxide pollution index has a long-term correlation over a long-time scale (more than four years). When the time scale is larger than one year, the series is more persistent, that is, in a larger time scale, the sulfur dioxide pollution index is more stable. The change trend of the future pollution index is consistent with the change trend of the past. When the past pollution index is increasing (decreasing), the future pollution index is bound to increase (decreasing). This shows that the pollution index in the fourth year and the pollution index in the first year are not unrelated, but related. This may be closely related to the residence time of sulfur dioxide in the atmospheric system and the long-term transport process [3].

For particulate matter 10 pollution index, H1=0.8785 when the time is within one year; When H2=0.4848 for a period longer than one year, it indicates that the particulate matter 10 pollution index shows high persistence or long-term memory within a time scale of one year, while the time series shows slight anti-persistence or white noise within a time scale longer than one year, that is, the past pollution index affects the future pollution index within a year. But beyond the one-year range, the future pollution index will gradually no longer be affected by the pollution index of a year ago, or have little impact.

2.3. Guessing Possible Causes

Exploring the possible causes, the main pollutants in Xi'an have obvious variation characteristics under the dual action of topographic and meteorological conditions. Xi'an City is located in the middle of the Guanzhong Basin, the Qinling Mountains in the south are in the east-west direction, the north is the Loess Plateau, the west side is closed by the Longyuan, in the inland basin plain, the east is the ventilation port formed by Tongguan (a county in Shanxi Province) and the Yellow River, affected by the Tai-hang Mountains and Luliang Mountain, there is only the only opening in the northeast, and it is controlled by the topography of the two mountains and valleys in the Fenwei Valley (in Sichuan Province), showing the pocket-shaped landform of the north and south walls and the west side of the mouth. Under the influence of topography, the northeast wind is the dominant wind direction in winter. In contrast, the winter in Xi'an is mainly dominated by stable and calm weather, and the special topography makes the polluting particulate matter in the air in the Guanzhong Basin

at zero wind level retained and cannot spread to other places. When the upwind areas in the east and northeast carry a lot of pollutants, the topography of the Guanzhong Basin leads to the formation of a "garbage bag" that only enters pollutants and does not discharge pollutants to other cities, and the continuous interaction between foreign pollutants and their pollutants in the basin further leads to the aggravation of pollution in Xi'an, and the duration is long, about one year [4,5].

3. Conclusion

By studying the statistics of the two air pollutant indices in Xi'an, Shaanxi Province, for four years, the paper came up with:

For sulfur dioxide, an air pollutant, when the pollution index increases (decreases) in the past, the pollution index will inevitably increase (decrease) in the future, that is, the trend of the future pollution index is still consistent with the past trend. It can be seen that there is a close correlation between the pollution index of the fourth year and the pollution index of the first year. This may be closely related to the residence time and long-term transport process of sulfur dioxide in the atmospheric system.

PM10, an air pollutant, shows relatively high persistence in the time scale of 1 year and shows slight resistance to persistence on a time scale of more than 1 year, that is, the past pollution index has a profound impact on the future pollution index in 1 year. However, beyond the one-year range, the future pollution index will gradually no longer be affected by the pollution index of a year ago, or the influence will continue to decrease.

The reason for this phenomenon is related to the unique geographical location of Xi'an City in Shaanxi Province, where the topography of the Guanzhong Basin has formed "garbage bags" that only enter pollutants and do not discharge pollutants to other cities, and the continuous interaction between internal and external pollutants in the basin and its pollutants further leads to the intensification of Xi pollution, and it lasts for a long time.

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