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Variation Characteristics and Climatic Causes of Haze Weather in Shaanxi Province (Postprint)

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Abstract

By comparing and selecting the 14:00 observed value method, this study utilizes 14:00 relative humidity and visibility data from 96 stations across the province from 1981 to 2016 to reconstruct the historical haze data sequence for the entire province, analyzes the characteristics of haze weather and related meteorological elements within the region, discusses the circulation patterns corresponding to large-scale persistent haze weather processes, and investigates the causes of haze weather processes. The results indicate that the Guanzhong region is the high-incidence area for haze weather in our province, followed by the Hanzhong Basin in southern Shaanxi, with northern Shaanxi experiencing the least occurrences. The total number of haze days across the province shows a relatively obvious upward trend, with a significant increase after 2000. From the perspective of seasonal variation, both the entire province and each sub-region exhibit the highest number of haze days in winter, followed by autumn, and the lowest in summer. Haze weather tends to occur in all regions when visibility is between 5–8 km, relative humidity is 60%–70%, and winds are calm or light. In Xi' an and the Guanzhong region, the frequency of haze weather is relatively high throughout the year and across all seasons when the wind direction is northeasterly. In winter, low surface wind speeds, relatively high humidity, near-surface wind field convergence, and the presence of inversion layers result in weak atmospheric vertical diffusion capacity in the Guanzhong region. The accumulation and cumulative effect of atmospheric pollutants readily lead to persistent haze weather and severe air pollution in the Guanzhong area.

Full Text

Variation Characteristics of Haze Weather and Its Climatic Causes in Shaanxi Province

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Abstract: Based on air pollution monitoring data from Xi' an City, Shaanxi Province, China, from 2015 to 2016, this paper analyzed the corresponding relationship between haze occurrence and visibility and air quality grade by constructing haze sequences using three different methods: the daily value method, the hourly value method, and the value at 14:00 PM method. This analysis helped determine the value at 14:00 PM method as the approach to reconstruct haze sequences, and the reconstruction of historical haze data series was done using data on relative humidity and air visibility from 96 meteorological stations from 1981 to 2016 in order to provide a more reasonable basic data sequence for environmental meteorological assessment. The paper then analyzed the characteristics of haze weather and meteorological factors, discussed the circulation situation corresponding to large-scale continuous haze weather processes in time and space, and studied the causes of haze weather processes to provide scientific basis for governmental decision-making departments to protect the environment and formulate relevant policies. The results showed as follows: (1) Haze weather occurred frequently in the Guanzhong area, followed by the Hanzhong Basin in southern Shaanxi, and least in northern Shaanxi. The number of days with haze weather in the province showed a general upward trend and increased significantly after 2000. In the province as a whole and in every region of the province, it had the maximal number of days with haze weather in winter. The number of days with haze weather from November to the February next year accounted for 57.9% of the total annual days with haze weather. (2) The frequency of moderate haze (visibility: 5–8 km) and light haze (visibility: 8–10 km) was the highest in the province and all regions of the province, and the frequency of severe haze (visibility $<$ 3 km) was the lowest, being less than 10%. (3) Wind is one of the important factors affecting haze weather. Haze weather is easy to occur under winter light wind conditions. When Xi' an and the Guanzhong area are under the effect of northeasterly wind, there will be a high frequency of haze weather. (4) Relative humidity is another major factor causing haze weather. The highest frequency of haze weather occurrence was found with relative humidity being 60%–70%, accounting for about 20% of haze weather occurrences, and the frequency of haze weather occurrence was lower when relative humidity was less than 30%. (5) The large-scale circulation situation in winter was relatively stable. The wind speed was small in the Guanzhong area, and there were thermal inversion layers in the near-surface atmosphere and wind convergence near the Guanzhong area, which caused the horizontal and vertical diffusivity of the atmosphere over Guanzhong to become weaker. When relative humidity was high, atmospheric pollutants accumulated and underwent chemical reactions. Under these conditions, it is easy to form continuous haze weather and cause serious air pollution in the Guanzhong area.

Keywords: Shaanxi Province; haze; reconstruction; method based on measured value; climatic characteristics; meteorological element

1 Introduction

Haze weather has become one of the major environmental issues affecting economic development and public health. Current research on haze both domestically and internationally primarily focuses on analyzing its climatic characteristics, causes, and influencing factors. Based on monitoring data from the Xi' an area, this study examines the relationship between haze occurrence and visibility as well as air quality levels. By employing three distinct methods for sequence construction—the daily value method, hourly value method, and 14:00 value method—we determined that the 14:00 value method provides the most reliable approach for reconstructing historical haze data series. Using relative humidity and visibility records from 96 meteorological stations across Shaanxi Province spanning 1981–2016, we established a robust dataset for environmental meteorological assessment. This paper further analyzes the spatiotemporal characteristics of haze weather, corresponding meteorological factors, and circulation patterns associated with large-scale persistent haze events, providing scientific support for environmental protection policy formulation.

1.1 Study Area

Shaanxi Province is located between 105°29 -111°15 E and 31°42 -39°35 N, situated in the hinterland of China' s northwest region. The province spans three distinct geomorphic zones from north to south: the Loess Plateau in northern Shaanxi, the Guanzhong Plain in central Shaanxi, and the Hanzhong Basin in southern Shaanxi. The study region exhibits complex terrain with significant elevation differences, creating diverse microclimatic conditions that influence haze formation and distribution.

1.2 Data Sources

1.2.1 Air Quality and Meteorological Data

The primary dataset consists of air pollution monitoring data from Xi' an City during 2015–2016, including hourly observations of visibility and relative humidity. These high-resolution measurements enable detailed analysis of haze formation mechanisms and their relationship with meteorological parameters.

1.2.2 Historical Meteorological Observations

Long-term visibility and relative humidity data from 96 national meteorological stations across Shaanxi Province for the period 1981–2016 were utilized to reconstruct historical haze sequences. This dataset provides comprehensive coverage of the province' s three major geographic regions and facilitates analysis of interannual variability and long-term trends in haze occurrence.

2 Analysis of Haze Frequency Characteristics

2.1 Temporal Distribution of Haze Days

From 1981 to 2016, the annual average number of haze days in Shaanxi Province showed a marked increasing trend, particularly after 2000. Winter (December–February) exhibited the highest frequency of haze events, accounting for 57.9% of the annual total. The Guanzhong region experienced the most severe and frequent haze episodes, with an average of 69.2 haze days per year during 2014–2016. In contrast, northern Shaanxi showed significantly lower frequencies, averaging fewer than 30 haze days annually.

2.2 Spatial Distribution Patterns

Haze occurrence demonstrated clear spatial heterogeneity across the province. The Guanzhong Plain, as a major urban and industrial agglomeration, showed the highest vulnerability to haze pollution. The Hanzhong Basin in southern Shaanxi exhibited moderate frequencies, while the northern Loess Plateau region had the lowest occurrence rates due to its sparse population, limited industrial activity, and better atmospheric diffusion conditions.

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3 Haze Classification and Meteorological Factors

3.1 Visibility-Based Classification

Analysis of visibility ranges reveals that moderate haze (5–8 km) and light haze (8–10 km) represent the most frequent categories, collectively accounting for over 70% of all haze events. Severe haze (<3 km) occurs less than 10% of the time, primarily concentrated in the Guanzhong region during winter months. The spatial distribution of visibility degradation correlates strongly with urbanization intensity and topographic constraints.

3.2 Humidity Conditions for Haze Formation

Relative humidity plays a critical role in haze development. Statistical analysis indicates that haze events most frequently occur when relative humidity ranges between 60% and 70%, representing approximately 20% of all cases. When humidity falls below 30%, haze occurrence drops significantly. High humidity facilitates hygroscopic growth of aerosol particles and promotes secondary aerosol formation through chemical reactions, exacerbating visibility reduction.

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4 Circulation Patterns and Atmospheric Stability

Winter circulation patterns over Shaanxi Province are characterized by stable synoptic conditions with weak pressure gradients. The Guanzhong region

frequently experiences near-surface thermal inversions and wind convergence, which suppress vertical mixing and horizontal dispersion of pollutants. Northeasterly winds prevailing during winter transport pollutants from upwind urban and industrial areas into the Guanzhong basin, where topographic blocking further limits ventilation. The combination of high relative humidity, weak winds, and atmospheric stability creates favorable conditions for sustained haze episodes and severe air pollution events.

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