

Variation in Human Comfort in Shaanxi Province and Its Response to Meteorological Factors: Postprint

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Abstract

Utilizing multi-year daily observation data from 96 national meteorological stations in the province, this study statistically analyzes the Human Comfort Index (CIHB) and investigates the influence of various environmental factors on human thermal comfort levels. The results indicate: From 1981 to 2016, both comfort levels and the number of comfortable days in Shaanxi Province exhibited a spatial pattern of fewer in the north and more in the south, decreasing with altitude. Specifically, the multi-year average number of comfortable days at nine stations including Hanzhong exceeded 200 d, while at seven stations including Yulin it was less than 120 d; Comfort frequency in each region showed a distinct unimodal distribution, with higher comfortable-grade frequencies in Northern Shaanxi during July–August, in the Guanzhong region during June–August, and in Southern Shaanxi during June–September; The provincial annual average CIHB was 45.7, with 92.4 comfortable-grade days. Both CIHB and the number of comfortable-grade days exhibited two peaks during 1998–1999 and 2008–2009; The correlation between air temperature and the comfort index was extremely significant, with a correlation coefficient as high as 0.9605. Average wind speed was significantly negatively correlated with CHIB, while relative humidity was significantly positively correlated with the comfort index under high-temperature conditions.

Full Text

Preamble

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Variation of Comfort Index of Human Body and Its Response to Meteorological Factors in Shaanxi Province

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Abstract

This study analyzes the comfort index of human body (CIHB) in Shaanxi Province using daily meteorological data (temperature, relative humidity, and wind speed) from 96 stations during 1981–2016. The purposes were to classify meteorological comfort levels, discuss the influence of various environmental factors on CIHB, and provide evidence for evaluating people's living environments and technical support for government decision-making. The results show that: (1) From 1981 to 2016, the variation trends of CIHB and comfort days in Shaanxi Province were consistent, with lower values in the north and higher values in the south, decreasing with increasing elevation. The highest CIHB values occurred in the Hanzhong Basin, where the average annual comfort days at Hanzhong and 8 other stations exceeded 200 days; the lowest values occurred in northern Shaanxi, where the average annual comfort days at Yulin and 6 other stations were less than 120 days. (2) The comfort frequency curves in all regions were unimodal. The highest frequency of comfort days in southern Shaanxi (84%) occurred in June, while that in northern Shaanxi and Guanzhong (80%) occurred in July. The frequency of comfort level was high in northern Shaanxi from July to August, in Guanzhong from June to August, and in southern Shaanxi from June to September, revealing that the time span and occurrence frequency of comfort level in Shaanxi Province decreased gradually from south to north. (3) In recent years, the average CIHB for the whole province was 45.7, the average comfort level days were 92.4, and the average frequency was 44.1%. Both the average CIHB and comfort level days showed an increasing trend, with obvious periodic changes. Two peak values of CIHB and comfort level days occurred during 1998–1999 and 2008–2009, respectively. (4) There was a significant positive correlation between temperature and CIHB, with a correlation coefficient as high as 0.9605. Relative humidity showed a significantly negative correlation with CIHB, but a significantly positive correlation when temperature was high. Average wind speed was negatively correlated with CIHB. Generally speaking, changes in CIHB were mainly caused by changes in climatic factors.

Keywords: comfort index of human body; classification of comfort level; comfort day; comfort period; Shaanxi Province

1 Introduction

Human body comfort index is a comprehensive indicator that reflects the degree of comfort or discomfort of the human body under different meteorological conditions. It is of great significance for evaluating living environments and providing technical support for government decision-making. Previous studies have shown that temperature, relative humidity, and wind speed are the main meteorological factors affecting human comfort. The comfort index of human body (CIHB) has been widely used in climate assessment and environmental evaluation.

1.1 Study Area

Shaanxi Province is located between 105°29' -111°15' E and 31°42' -39°35' N, with complex terrain that is generally high in the north and low in the south. The province spans multiple climate zones, resulting in significant regional differences in meteorological conditions and human comfort levels.

1.2 Data and Methods

1.2.1 Data Sources

Daily meteorological data from 96 stations in Shaanxi Province during 1981-2016 were used, including temperature, relative humidity, and wind speed. The data were obtained from the Shaanxi Provincial Climate Center and the National Meteorological Information Center. Quality control procedures were applied to ensure data reliability.

1.2.2 Calculation of CIHB

The comfort index of human body was calculated using the following formula:

$$CIHB = 1.8t - 0.55(1.8t - 0.26)(1 - RH) - 3.2\sqrt{v} + 32$$

where t is temperature (°C), RH is relative humidity (decimal), and v is wind speed (m/s).

Based on the CIHB values, the meteorological comfort levels were classified into 9 grades, as shown in Table 1.

Table 1. Classification of comfort index of human body (CIHB)

CIHB Value	Comfort Level	Human Perception
86	4	Very hot, extremely uncomfortable
80-85	3	Hot, uncomfortable

CIHB Value	Comfort Level	Human Perception
76-79	2	Warm, relatively uncomfortable
71-75	1	Slightly warm, slightly uncomfortable
59-70	0	Comfortable
51-58	-1	Slightly cool, slightly uncomfortable
39-50	-2	Cool, uncomfortable
26-38	-3	Cold, very uncomfortable
25	-4	Very cold, extremely uncomfortable

2 Results and Analysis

2.1 Spatial Distribution Characteristics

The spatial distribution of CIHB in Shaanxi Province showed clear regional patterns. The CIHB values and comfort days were consistently lower in the north and higher in the south, decreasing with elevation. The Hanzhong Basin in southern Shaanxi exhibited the highest CIHB values, with average annual comfort days exceeding 200 days at Hanzhong and eight other stations. In contrast, northern Shaanxi showed the lowest values, with average annual comfort days less than 120 days at Yulin and six other stations.

[Figure 1: see original paper]

Fig. 1. Distribution of comfort index of human body from 1981 to 2016

The distribution of comfort days followed a similar pattern, with the number of comfort days gradually decreasing from south to north.

[Figure 2: see original paper]

Fig. 2. Distribution of comfort days from 1981 to 2016

2.2 Temporal Variation Characteristics

The temporal variation of CIHB showed significant seasonal and interannual patterns. The highest frequency of comfort days occurred in summer months, with southern Shaanxi peaking in June (84%) and northern Shaanxi and Guanzhong peaking in July (80%). The comfort period lasted from July to August in northern Shaanxi, June to August in Guanzhong, and June to September in southern Shaanxi, indicating that both the duration and frequency of comfortable conditions decreased from south to north.

Over the 36-year study period, the average CIHB for the entire province was 45.7, with an average of 92.4 comfort days per year and an average frequency of 44.1%. Both CIHB and comfort days exhibited an increasing trend with obvious periodic fluctuations. Two distinct peaks occurred during 1998-1999 and 2008-2009.

2.3 Correlation Analysis

Correlation analysis revealed that temperature was the dominant factor influencing CIHB, with a significant positive correlation coefficient of 0.9605. Relative humidity showed a significantly negative correlation with CIHB overall, but this relationship reversed to positive when temperature was high. Wind speed demonstrated a consistently negative correlation with CIHB. These results indicate that changes in CIHB were primarily driven by variations in climatic factors, particularly temperature.

[Figure 6: see original paper]

Fig. 6. The linear relation between average air temperature and CIHB

[Figure 7: see original paper]

Fig. 7. Correlation coefficients among monthly mean temperature, relative humidity, wind speed and CIHB

The multiple correlation coefficient between temperature, relative humidity, wind speed and CIHB reached 0.9605, indicating that these three meteorological factors collectively explained most of the variation in human comfort levels across Shaanxi Province.

3 Discussion

The spatial distribution of CIHB in Shaanxi Province is closely related to the complex terrain and climate zoning. The southern region benefits from higher temperatures and humidity, resulting in more comfort days, while the northern region experiences colder and drier conditions, leading to fewer comfort days. The increasing trend of CIHB over the study period may reflect regional climate warming, which has extended the duration of thermally comfortable conditions in many areas.

The strong correlation between temperature and CIHB ($r = 0.9605$) underscores the predominant role of temperature in determining human comfort. However, the modifying effects of humidity and wind speed cannot be neglected, especially during extreme temperature conditions. The negative correlation between wind speed and CIHB suggests that higher wind speeds generally reduce thermal comfort, likely through enhanced convective heat loss.

4 Conclusion

This study analyzed the spatiotemporal variation of the comfort index of human body and its response to meteorological factors in Shaanxi Province from 1981 to 2016. The main conclusions are:

1. CIHB values and comfort days showed clear spatial gradients, decreasing from south to north and with increasing elevation. The Hanzhong Basin

had the most comfortable conditions, while northern Shaanxi had the least.

2. The comfort period exhibited distinct seasonal patterns, with summer months showing the highest frequency of comfortable days. The duration of comfortable conditions decreased gradually from southern to northern Shaanxi.
3. Interannual trends showed an overall increase in CIHB and comfort days, with notable peaks during 1998–1999 and 2008–2009, reflecting periodic climate variations.
4. Temperature was the primary controlling factor for CIHB, with a correlation coefficient of 0.9605. Relative humidity and wind speed also significantly influenced comfort levels, with their effects depending on temperature conditions.

These findings provide a scientific basis for evaluating living environments, guiding urban planning, and developing climate adaptation strategies in Shaanxi Province.

References

- [1] National Climate Center. *China Climate Impact Assessment* [M]. Beijing: China Meteorological Press, 2004: 113-114.
- [2] Yang Chengfang. *Study on Climate Comfort Index in Shandong Province* [D]. Qingdao: Ocean University of China, 2004.
- [3] Dong Huiqing, Huang Haihong, Huang Xiangxing, et al. Prediction system of human comfortableness of coastal cities in the east China [J]. *Progress in Geographical Analysis of Climate Suitability Degree for Human Settlement Environment in Zhejiang Province*, 2017, 40(1): 120-125.
- [4] Wu Dui, Deng Xuejiao. *Environmental Meteorology and Special Meteorological Forecasts* [M]. Beijing: China Meteorological Press, 2001: 162-189.
- [5] He Jing, Tian Yongzhong, Gao Yanghua, et al. Climate suitability assessment of human settlements in Chongqing mountainous areas [J]. *Journal of Southwest University (Natural Science Edition)*, 2010, 32(9): 100-106.
- [6] Hu Lin, et al. Variation of comfort index of human body and its response to meteorological factors in Shaanxi Province [J]. *Acta Geographica Sinica*, 2019, 74(6): 1123-1135.

Note: Figure translations are in progress. See original paper for figures.

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