# Analysis of Diurnal Temperature Variation Characteristics in the Main Urban Area of Urumqi (Postprint)

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## Abstract

Utilizing hourly temperature observation data from automatic weather stations during 2008-2020, this study investigates the diurnal variation characteristics of temperature in the main urban area of Urumqi. The results indicate that: The daily maximum temperature in Urumqi' s main urban area occurs primarily between 14:00-17:00, while the daily minimum temperature occurs between 05:00-08:00. Within the same season, the occurrence times of daily maximum temperature across different months differ by at most 1 h; however, the occurrence times of daily minimum temperature exhibit greater variation among winter months, with December and January differing from February by 4 h. Moreover, the daily minimum temperature in December and January occurs 2-3 h earlier than in other months, representing a significant difference compared to other cities in China. The diurnal distribution curves of maximum temperature occurrence frequency for each month predominantly exhibit a 'bimodal' pattern, with the main peak occurring between 15:00-18:00 and the secondary peak at 21:00. The temporal distribution of occurrence frequency for daily maximum temperature across different hours is more concentrated during summer and winter months, while relatively dispersed during spring and autumn. The diurnal distribution curves of minimum temperature occurrence frequency display a 'unimodal' pattern in spring, summer, and autumn, whereas the peak characteristics are less pronounced in winter. During spring, summer, and autumn, the minimum temperature occurs with higher frequency between 07:00-10:00, while in winter (December and January), the occurrence frequency is relatively higher at 20:00. In the main urban area, the 1 h positive temperature change is greater during 09:00-12:00, and the 1 h negative temperature change is greater during 18:00-22:00, indicating asymmetry between positive and negative temperature changes, with 1 h temperature change being the dominant factor in temperature variation in Urumqi' s main urban area. The diurnal variation characteristics

of temperature in Urumqi' s main urban area during winter are more complex than in the other three seasons.

## Full Text

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### Diurnal Temperature Variation Characteristics in the Main Urban Area of Urumqi

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Temperature is a crucial meteorological indicator affecting human daily life and ecological environments, and serves as an important metric for forecasting disastrous weather events such as heatwaves, cold waves, frost, and low-temperature damage [ ]. Diurnal variation represents a fundamental characteristic of climate [ ], and understanding temperature diurnal variation patterns is essential for elucidating relationships between atmospheric circulation evolution and diurnal cycles, as well as for improving refined temperature forecasting and disaster weather prediction accuracy [ ]. Due to limitations in observational technology, early research on temperature diurnal variation was relatively coarse in both spatial and temporal scales, making comprehensive understanding of its intrinsic characteristics difficult. With continuous improvement of global meteorological observation networks, we now have access to higher spatiotemporal resolution meteorological data, providing necessary support for systematic investigation of temperature diurnal variation [ ].

Previous studies have demonstrated that different underlying surface conditions and sky states affect the timing of daily maximum and minimum temperatures in a region [ ]. For instance, research using Beijing' s automatic weather station data analyzed diurnal temperature differences and seasonal characteristics between urban and suburban areas, identifying urban heat capacity differences as the primary cause of temperature disparities [ ]. Hu et al. [ ] compared diurnal temperature variations between urban and suburban representative stations in Hong Kong using hourly temperature data. Huang et al. [ ] observed and compared four different underlying surfaces in Nanjing, finding that daytime temperatures followed the trend forest land < water body < grassland < concrete, with the opposite pattern at night. Zheng et al. [ ] analyzed summer temperature diurnal variation characteristics and spatiotemporal distribution in Shenzhen, revealing that urban built-up areas had lower heating and cooling rates than suburban areas, with horizontal temperature variation distributions directly influenced by differences in urban surface heat capacity, geography, topography, and local wind circulation. Lyu et al. [ ] noted that due to solar radiation diurnal variation, near-surface maximum temperatures in most regions of China generally occur between 14:00–15:00 Beijing Time, while minimum temperatures appear around sunrise. Underlying surface conditions, weather phenomena, and other factors cause rapid heating rates after sunrise and gradual temperature change rates at night [ ].

Cities constitute important components of Earth' s surface and represent the most active areas of human activity, significantly influencing regional climate change and ecological environments. In recent years, with China' s rapid urbanization, the impact of urbanization on temperature change has attracted increasing attention [ ]. Urumqi, capital of the Xinjiang Uygur Autonomous Region, has experienced rapid urban development. However, the characteristics of diurnal temperature variation under complex urban underlying surfaces in Urumqi' s main urban area remain unclear. Previous Urumqi temperature studies have primarily focused on interdecadal, interannual, and seasonal timescales, emphasizing long-term trends and urbanization effects [ ], while research on refined urban temperature characteristics, particularly diurnal variation, remains limited. Although some scholars have investigated temperature variation features using daily mean temperature and daily maximum/minimum temperature data [ ], few studies have employed higher temporal resolution automatic weather station hourly temperature data to examine diurnal temperature characteristics in Urumqi. To further understand refined temperature features in Urumqi, this study utilizes hourly temperature observations from Urumqi' s main urban area automatic weather stations (2008–2020) to analyze diurnal patterns of extreme temperatures and temperature variation rates, providing references for refined weather forecasting and services.

### 1.1 Data

This study employs hourly temperature observation data from Urumqi National Basic Weather Station (87°39 00 E, 43°47 00 N, elevation 918.7 m) provided by the Meteorological Information Center of Xinjiang Meteorological Bureau. The automatic weather station data were quality-controlled, with abnormal values and incomplete records removed.

### 1.2 Research Methods

Following definitions in reference [ ] regarding occurrence frequency and temperature variation: (1) Occurrence frequency is defined as the ratio of occurrence counts to total counts, characterizing the probability of daily maximum (minimum) temperature appearing at specific hours. (2) Temperature variation refers to the temperature change magnitude per unit time, representing an important indicator for assessing weather process intensity in forecasting. This study focuses on analyzing 1-hour and 3-hour temperature variations.

# 2 Results and Analysis

## 2.1 Diurnal Temperature Variation Characteristics

Figure 1 shows the diurnal temperature variation distribution in Urumqi' s main urban area from May to August. The daily maximum temperature occurs earliest in July at 14:00, while other months peak at 15:00 or 16:00. Daily minimum temperatures occur at 05:00 in May and June, 07:00 in July and August, and 08:00 in other months. Within the same season, monthly maximum temperature occurrence times differ by at most 2–3 hours, whereas minimum temperature occurrence times show greater inter-monthly variation in winter. Specifically, December and January minimum temperatures occur at 05:00, 2–3 hours earlier than other months, representing a significant difference from other Chinese cities.

The diurnal distribution curve of maximum temperature occurrence frequency exhibits a "bimodal" pattern (except in December and January), with primary peaks at 15:00–18:00 and secondary peaks at 07:00–10:00. Occurrence frequencies at primary peaks range from 19.7% to 33.6%, with July showing the highest frequency (33.6%) and January the lowest (19.7%). Secondary peak frequencies range from 14.5% to 24.9%, with December highest (24.9%) and July lowest (14.5%). Summer and winter months show concentrated temporal distributions of maximum temperature occurrence frequencies, while spring and autumn display more dispersed patterns.

Minimum temperature occurrence frequency curves show a "unimodal"pattern in spring, summer, and autumn, with peak frequencies occurring at 07:00 in May and June (35.7% and 43.7%, respectively), 09:00 in July and August (36.7% and 37.6%), and 10:00 in September and October (33.9% and 28.9%). Winter months exhibit less distinct peak characteristics, with December showing peak frequency at 20:00 (17.7%) and January at 20:00 (15.4%). The maximum minimum temperature occurrence frequency is highest in summer (49.4% in August) and lowest in winter (15.4% in January).

Previous research indicates that near-surface extreme minimum temperatures in mainland China typically occur around sunrise, which is earlier in summer than winter. However, Urumqi' s minimum temperature occurrence times in winter contradict this general pattern, appearing earlier than in summer—a phenomenon differing from other Chinese cities [ ]. Urumqi' s unique geographical location on the northern slope of the Tianshan Mountains and its complex topography, combined with frequent winter temperature inversions and foggy conditions, may contribute to these distinctive diurnal temperature characteristics. Recent trends show significantly increasing winter fog days in Urumqi, likely influencing these temperature patterns.

### 2.3 Diurnal Variation Characteristics of Temperature Change

Figure 4 illustrates the diurnal variation of 1-hour temperature changes in Urumqi' s main urban area. Positive (warming) and negative (cooling) temperature changes show asymmetric patterns, with positive changes significantly larger than negative changes. Maximum positive temperature changes occur between 09:00–12:00, while maximum negative changes appear between 18:00–22:00. Maximum temperature change magnitudes range from 1.2–1.9°C for positive changes and 0.9–1.2°C for negative changes.

Taking July as an example, positive temperature change reaches its maximum at 10:00–12:00, completing the warming process in approximately 2–3 hours. Negative temperature change peaks at 19:00–23:00, requiring about 4–5 hours, indicating a slightly more gradual cooling process. The average maximum temperature change rate in Urumqi' s main urban area is $0.61°\mathrm{C} \cdot \mathrm{h}^{-1}$ for positive changes and $0.44°\mathrm{C} \cdot \mathrm{h}^{-1}$ for negative changes, with minimal seasonal differences for positive changes but greater variation for negative changes (Table 1).

Analysis of 3-hour temperature variation (Figure 5) reveals similar asymmetric patterns, with more dispersed distributions compared to 1-hour variations. The most intense temperature change processes in Urumqi' s main urban area are typically completed within 3 hours.

### 2.4 Probability Distribution of Maximum Positive/Negative Temperature Change Occurrence Times

Figure 6 shows the diurnal distribution of maximum positive temperature change occurrence rates. Peak frequencies appear between 10:00–12:00, with the highest frequency in summer (39.2% at 11:00). Seasonal distributions are relatively uniform, with peak occurrence times consistent within seasons except for spring. Winter shows the lowest peak frequency (29.4%).

Figure 7 presents the diurnal distribution of maximum negative temperature change occurrence rates. Peak frequencies occur between 18:00–23:00, with the highest frequency in autumn (21.5% at 19:00) and the lowest in winter (17.0%). The distribution curve for maximum negative temperature change is more dispersed than that for positive changes. In all seasons, the occurrence probability of maximum positive/negative temperature change is lowest for 3-hour variations.

## 3 Conclusions

Using hourly temperature data from automatic weather stations (2008–2020), this study analyzed diurnal patterns of maximum/minimum temperatures and temperature variation rates in Urumqi' s main urban area. Key findings include:

1) Daily maximum temperatures occur between 14:00–17:00, while minimum temperatures appear between 05:00–08:00. Within seasons, monthly max-

imum temperature occurrence times differ by at most 2–3 hours, but minimum temperature occurrence times show substantial variation in winter, with December and January minima appearing at 05:00, 2–3 hours earlier than other months—a pattern differing significantly from other Chinese cities.

2) The diurnal distribution of maximum temperature occurrence frequency exhibits a bimodal pattern, with concentrated temporal distributions in summer and winter months and more dispersed patterns in spring and autumn. Minimum temperature occurrence frequency shows a unimodal pattern in spring, summer, and autumn, with less distinct peak characteristics in winter. The maximum occurrence frequency of minimum temperature appears at 07:00–10:00 in spring, summer, and autumn, but at 20:00 in winter, contradicting general patterns influenced by solar radiation diurnal variation.

3) The 1-hour temperature variation magnitude ranges from 1.2–1.9°C for positive changes (09:00–12:00) and 0.9–1.2°C for negative changes (18:00–22:00). Positive and negative temperature changes exhibit asymmetry, with cooling processes slightly more gradual than warming processes. The average maximum temperature change rate is primarily completed within 3 hours.

4) The most probable times for maximum positive temperature change occur between 10:00–12:00, with peak frequencies highest in summer (39.2%) and lowest in winter (29.4%). Maximum negative temperature change most likely occurs between 19:00–23:00, with peak frequencies highest in autumn (21.5%) and lowest in winter (17.0%). The diurnal distribution curve for maximum negative temperature change shows greater dispersion than that for positive changes.

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