The Variation Law of Different Underlying Surface Temperature and Urban Temperature

Yifu Wang\textsuperscript{1} and Lei Yuan\textsuperscript{1,2*}

\textsuperscript{1}School of Information Science and Technology, Yunnan Normal University, Kunming, China
\textsuperscript{2}Engineering Research Center of the Ministry of Education on Geography Information Technology of Western Resource Environment, Kunming, China
\textsuperscript{*}Corresponding author’s e-mail: v_ict@163.com

Abstract. The rapid development of urbanization has changed the type of underlying surface within the city and affected the temperature changes in the city. Mastering the relationship between urban temperature and the temperature of the different underlying surface is the basis for improving the urban heat island effect. To this end, select the school with representative urban characteristics to study the relationship between urban temperature and urban underlying surface types under different weather conditions. The Chenggong Campus of Yunnan Normal University in Kunming, Yunnan Province is the typical urban research object. Extracting the underlying surface type data of four main active areas such as grassland, water surface, bare soil and asphalt by means of artificial field measurement, and analyzed. The experimental results show that under different underlying conditions, the influence of environmental climatic conditions on urban temperature is different. This shows that in urban planning, the rational planning and design of different underlying surface types can effectively solve the urban heat island and rain island effect problem.

1. Introduction

The city is a concentrated expression of human activities. Since the 20th century, with the expansion of urban areas and the further development of urbanization, the difference between urban temperature and suburban temperature will further increase, which will significantly affect urban environment, climate change and residents' quality of life\textsuperscript{[1-3]}. The Urban Heat Island (UHI) is the most typical manifestation of the impact of urbanization on urban climate. Urban heat islands, as a product of urbanization, are a phenomenon in which urban temperatures are significantly higher than those in suburbs\textsuperscript{[4]}. Through in-depth study of the urban heat island effect, scholars in various fields have found that the type of urban underlying surface is closely related to the urban heat island effect\textsuperscript{[5]}. The acceleration of urbanization has caused significant changes in land cover types. Large areas of bare land and cultivated land have been replaced by impervious surfaces such as artificial buildings, asphalt, cement, concrete, etc., resulting in a decrease in latent heat flux and an increase in sensible heat flux. It is the main factor affecting surface temperature\textsuperscript{[6]}, and surface temperature is one of the core elements of urban space thermal environment\textsuperscript{[7]}. The increase in urban buildings and the excessive emissions of urban heat create a hot airflow over the city that eventually leads to precipitation. At the same time, the concentrated buildings in the city reduce the wind speed and the time formed by the strong rain belt weather system over the city is longer than that of the open suburbs. Then urban rain island is formed. In the context of the global climate, this effect will increase the chance of heavy rain and flooding, and the obvious “cementation” and “hardening” of the underlying surface of the city will
make the surface water formed by precipitation unable to penetrate into the ground effectively, which will result in a large amount of water and guilt in the city. It also causes water pollution problems such as sewage leakage and drinking water source pollution. The urban heat island effect can not alleviate the environmental pollution in urban areas, and reduce urban air quality, which will have a serious impact on the health of urban residents[8].

Therefore, the study of the relationship between urban temperature and temperature of different underlying surface is of great significance for improving the urban thermal environment. In this paper, the continuous observation data of four typical cities’ underlying surface such as asphalt, bare land, grassland and water surface are used. The relationship between urban temperature and different types of underlying surface temperature is systematically analyzed, which can provides a theoretical basis for improving urban heat island effect.

2. Research Area and Method

2.1. Research Area
Kunming, the capital of Yunnan Province, is located in the central part of the Yunnan-Guizhou Plateau and the monsoon climate of the low-latitude plateaus of the northern subtropics. The annual average temperature is 16.5°C, the average annual rainfall is 1,450 mm, and the climate is pleasant.

The observation area is located in the Chenggong campus of Yunnan Normal University in Kunming. The typical underlying surface of four kinds of cities including asphalt pavement, grassland and bare water surface is selected for surface temperature observation. The surrounding area of the observation area is relatively empty and there are no tall buildings. The observation time is from November 22, 2018 to December 22, 2018, and the fixed area is observed at 10:00, 14:00, and 18:00 every day.

2.2. Observation Method and Analysis Method
The Fluke 62 MAX infrared thermometer is used to measure the temperature of the four underlying surfaces, and the measured temperature can be displayed in real time. When measuring temperature, the thermometer is perpendicular to the ground, and the same height is maintained with the ground. Multiple measurements are made in the observation area to obtain the maximum value, the minimum value, and the average value.

The temperature of the observation site is measured by the Testo610 temperature and humidity meter. Its temperature accuracy is ±0.5°C and the humidity accuracy is ±2.5%. The measurement data can be displayed in real time. When measuring temperature, the instrument remains stationary, and after waiting for the value to stabilize, record the data.

3. Results and Analysis

3.1 Variation Characteristics of Different Underlying Surface Temperature

3.1.1 Daily Maximum Temperature
The monthly daily variation trend of the maximum daily temperature of the four underlying surfaces is consistent with the daily maximum air temperature. The extreme values of bare soil and grassland appear the same as asphalt, and the highest and lowest values appear on December 12 and 8 respectively (Figure1 a). Except for the water surface, the daily maximum temperature of the other three underlying surfaces is significantly higher than the daily maximum temperature. The average daily maximum temperature is the highest in asphalt (43.7°C), followed by bare land and grassland, and the difference between the two is not significant, and the water surface is the lowest. Asphalt, bare land and grassland were higher than the air temperature, which were 19.4, 3.5 and 1.1°C respectively (Table 1).
3.1.2 **Daily Minimum Temperature**
The monthly daily minimum temperature changes of the four underlying surfaces were consistent with the daily minimum temperature of air, showing a bimodal change. The maximum appeared on November 24 and 26, the minimum appeared on November 27 (Figure 1b). The lowest daily minimum temperature of bare land is the highest (12.0°C), followed by grassland, asphalt, and water surface. Compared with the air temperature, the bare land is 0.6°C higher, and the water surface, asphalt and grassland are lower at 1.9, 1.7, and 0.8°C respectively (Table 1).

3.1.3 **Daily Average Temperature**
The daily average temperature change trend of the four underlying surfaces is consistent with the air temperature. The highest values appeared on December 11 and the lowest values appeared on December 8 (Figure 1c). Except for the water surface, the average daily temperature of the other three underlying surfaces is significantly higher than the daily average air temperature, and the asphalt temperature is more significant. The average daily temperature is the highest in asphalt (25.2°C), followed by grassland (18.0°C), and followed by grassland. Compared with the water surface, the average temperatures of asphalt, grassland, bare land and air temperature were 12.2, 5.0, 4.4 and 3.3°C higher respectively (Table 1).

3.1.4 **Daily Range**
The daily range trend of the four underlying surfaces is consistent with the air temperature, and the average daily difference of asphalt is the largest (Figure 1d). As far as the test cycle is concerned, the daily range of air temperature and water surface are similar, both of which are the highest on November 25 and the lowest on December 27. The average daily asphalt is the highest (34.0°C), the second is bare land, followed by grassland (the difference is not significant), and the water surface is the lowest (6.1°C). Compared with the water surface, asphalt, bare ground, grassland and air temperature were 27.9, 9.7, 8.7, and 6.8°C higher respectively (Table 1).

**Table 1.** Comparison of temperature and temperature of underlying surface in 4 cities (temperature unit: °C).

|                      | Air temperature | Asphalt | Water surface | Grassland | Bare soil |
|----------------------|-----------------|---------|---------------|-----------|-----------|
| Daily maximum temperature | 24.3            | 43.7    | 15.6          | 25.4      | 27.8      |
| Daily minimum temperature | 11.4            | 9.7     | 9.5           | 10.6      | 12.0      |
| Daily average temperature | 16.3            | 25.2    | 13.0          | 18.0      | 17.4      |
| Daily range           | 12.9            | 34.0    | 6.1           | 14.8      | 15.8      |
In summary, the daily average temperature, daily maximum temperature, and daily minimum temperature variation of the four underlying surfaces are similar to air temperature changes. It is worth noting that asphalt, the impervious underlying surface, has heat absorption and dissipation characteristics, and its daily maximum temperature and daily range are significantly higher than the other three underlying surfaces. The reasons may be: (1) Asphalt is darker in color, less reflectivity, that can absorb more radiant energy under the same solar radiation conditions; (2) The specific heat of the asphalt is smaller (close to the bare soil); (3) The thermal radiation heat dissipation at night is strong, causing its daily minimum temperature is lower than bare soil. Bare soil and grassland as the water-permeable underlying surface are all susceptible to soil moisture, and the temperature characteristics tend to be consistent. However, due to the turf covering the underlying surface of the grass, the heat preservation is good, and the daily difference is lower than that of bare soil.

4. Conclusion
The surface of the earth heats up by absorbing short-wave radiation from the sun, while cooling through sensible heat and long-wave radiation. Due to the different properties of different underlying surfaces, the temperature changes will also vary greatly. When the temperature of the underlying surface is higher than the temperature, the atmosphere is heated, and vice versa, the atmosphere is cooled. At present, most of China's urban roads and buildings are made of cement and asphalt, and the area is still rising gradually. These impervious underlying surfaces have lower reflectivity and smaller heat capacity, which contributes the most to the urban thermal environment\[^{9-10}\]. The trend will further
expand the temperature difference between urban and rural areas and accelerate the formation of urban heat islands. The results show that, except for the water surface, the daily average temperature and daily maximum temperature of the underlying surface of the other three typical cities are higher than the temperature, indicating that the typical urban underlying surface has a certain heating effect on the atmosphere, among which the asphalt is the strongest, followed by bare soil, grassland. Through the ground-atmosphere interaction, the urban underlying surface has an impact on the regional climate.

5. References

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