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STUDY ON OUTDOOR THERMAL ENVIRONMENT OF CAMPUS BASED ON GIS

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ABSTRACT: In recent years, the campus population and the buildings of Jiangsu University have increased and the pattern of the micro-city has preliminarily formed. The data of outdoor thermal environment of campus based on Geographic Information System (GIS) has found that the average temperature difference of outdoor temperature in space distribution in Jiangsu University is about 1℃. Five different underlying surfaces have a great influence on the outdoor thermal environment of campus, and the daily variation of temperature showed an inverted "V" single peak curve. The daily variation of temperature on the concrete road (direct sunlight) is approximately 4℃ above that of the grassland at the time of 14:00. The temperature of the concrete road (direct sunlight) is higher than that of the concrete road (shadows), and the temperature difference between them is about 1℃. At the same time, five suggestions have been proposed for the improvement of outdoor thermal environment in Jiangsu University according to the results.

Keywords: Heat Island Effect, Outdoor Thermal Environment, Spatial Change, Underlying Surface, GIS

1. INTRODUCTION

Urban heat island effect, whose temperature is higher than that of outer suburbs, reduces the comfortability of the manufacture and life of people, that endangers the health and even life of human [1, 2].With the warming of global, the influences of urban heat island effect on lives of people have become increasingly apparent. The rapid development of urban has accelerated the aggravation of urban heat island [3]. In recent years, the enrollment of Jiangsu University continues to expand, and the campus construction develops rapidly. The campus covers an area of 1,880,000 m^2. Among them, all types of building area hold more than 1,280,000 m^2, and nearly 50 thousand students are in school. With the increases of the campus population and buildings, the pattern of micro-city has preliminarily formed. Surface temperature change of different underlying surfaces is an important factor to improve urban heat island effect [4]. Accompanied by the increasingly obvious urbanization and huge development of the university campus, reducing the heat island effect has become an important topic to improve the learning and living environment of students, and create a comfortable outdoor environment [5, 6].

2. DATA MONITORING AND RESEARCH METHODS

2.1 Data Monitoring Methods

In this study, the Japanese advanced portable carbon dioxide measuring instrument (model C2D-W02TR) was adopted to measure the outdoor temperature and relative humidity of the campus of Jiangsu University. GIS was used to analyze and study the distribution characteristics of outdoor thermal environment in campus.

The research object is the whole area of campus in Jiangsu University, which is in east longitude 119°30′ ～ 119°31′30″E, and north latitude 32°11′40″～32°12′50″N. The campus area was divided into 30 measuring area with each 300m*300m as a measuring unit. A position with marked facility of each measuring unit was chosen as a measuring point for measuring the latitude and longitude to ensure that each measurement was performed at the same location (Fig. 1 and Fig. 2). All the measuring points were measured in three time periods at 7:00-8:00 in the morning, 10:00-11:00 at noon and 17:00-18:00 at evening for three times a week. The underlying surfaces of the measuring points were divided into 4 categories, such as grassland, lake, concrete and marble road to discuss the temperature and relative humidity changes of different underlying surfaces.

2.2 Data Analysis Method

In this work, Microsoft Excel 2013 software was used to database establishment, data collection and analysis. GRASS and GMT software were used to visualize the temperature spatial distribution data, which directly and quantitatively reflected the temporal and spatial distribution characteristics of temperature in the campus.

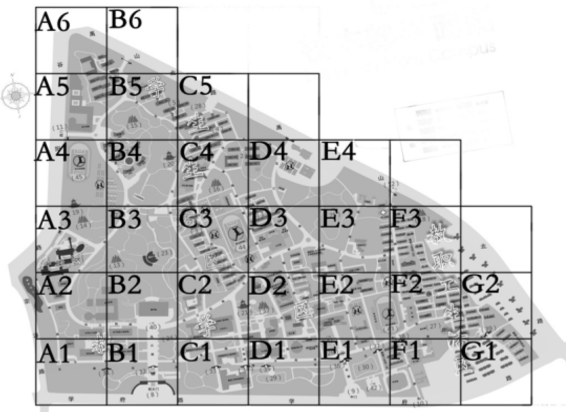

Fig.1 Area division of campus outdoor temperature measurement.

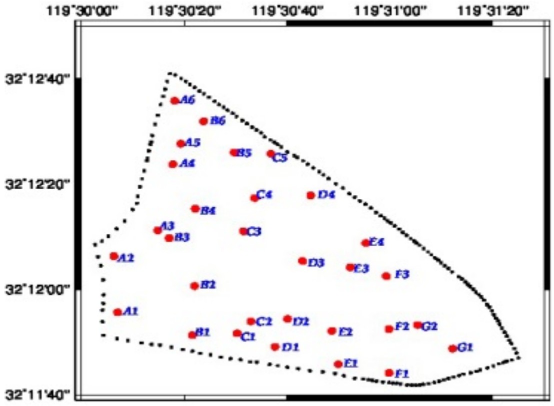

Fig.2 Point distribution of campus outdoor temperature measurement.

3. TEMPORAL AND SPATIAL DISTRIBUTION CHARACTERISTICS OF TEMPERATURE

As shown in Figure 3, the temperature difference of the average temperatures among morning, noon and evening is about 1℃. The lowest temperatures of morning, noon and evening was concentrated near the round covers in front of the auditorium (D3). This measuring point is at the crossroads with good ventilation, where a lawn is in the front and is sheltered by tall trees. The trees can block shortwave radiation of the sun and absorb long-wave radiation of the ground. The highest temperature in the morning appeared in sixth canteen corner of Jiangsu University (A6) and the main entrance in front of the Mechanical College (C2). The highest temperature at noon was under a ladder of Sanjiang Floor Front Gate (E2). The highest temperature in the evening was at the entrance to the auditorium (D2). Except for the factors of the concrete surface, tall buildings and poor ventilation in these places, the influences of the traffic and population also contributed to the high temperature. So the temperature is higher in the areas with lots of population and traffic, such as canteen and accommodation areas. The temperature was low in the areas with plentiful vegetation cover and a small quantity of population such as Thorpe plum. The temperature in the morning has bigger variation than that at noon and in the evening, which might be related to the sunshine, the wind speed, the underlying surface and the surrounding environment.

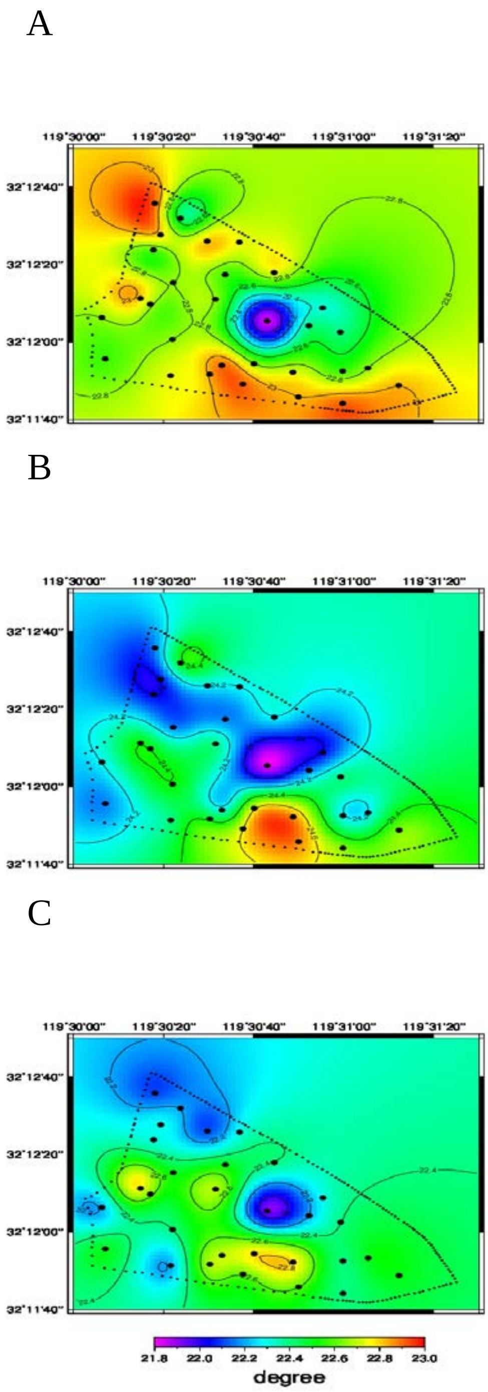

Fig.3 Temperature distribution in time interval (A: morning; B: noon; C: evening).

As shown in Figure 4, the low temperature region was centered near the round covers in front of the auditorium (D3), near the lawn opposite the Valentine Valley (E3) and the yellow road in front of expert floor (E4). At these places, trees not only can reduce the outdoor wind speed, making the heat accumulation phenomenon appeared, but also can remove a large amount of short-wave radiation by reflection and transmission through their leaves to decrease the surrounding ambient air temperature. The high temperature region was distributed in the middle of the round altar opposite the Three Hill building (D1), at the entrance to the lecture hall (D2), in the roadside of Jiangsu University (E1), and under the stairs at the main entrance of Sanjiang building (E2). The minimum temperature was 22.5℃ and the maximum temperature was 23.5℃. The average temperature difference was about 1℃. In this study, 300m*300m is a measurement unit, and the lowest and the highest temperature regions were only 1 to 2 measurement unit intervals. That is to say, in the range of 300m to 600m, the temperature has already changed 1℃. It shows that there was a more obvious heat island effect on the campus of Jiangsu University.

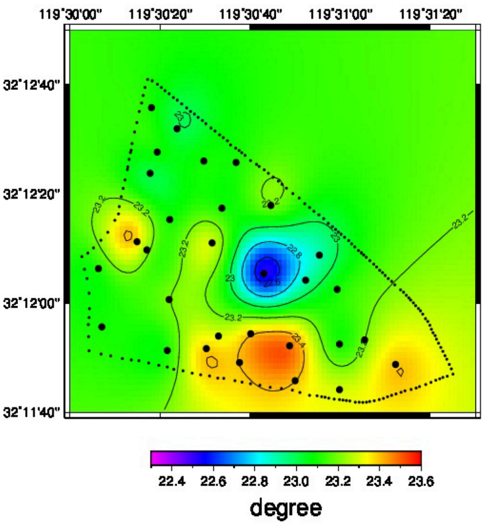

Fig. 4 Spatial distribution of the mean temperature.

In order to further investigate the effect of heat island effect, we select five measurement points to study the influences of different underlying surfaces according to the results of Figure 4. Grassland (E3), riverside (F2), marble road (E2), concrete road with (C5) and without (C4) shadow were chosen for studying the changes of the temperature and relative humidity around their surrounding environments.

4. CHARACTERISTICS OF TEMPERATURE AND RELATIVE HUMIDITY AT DIFFERENT UNDERLYING SURFACES

4.1 Daily Variation of Temperature at Different Underlying Surfaces

As shown in Figure 5, temperatures of five different underlying surfaces in one day presented inverted "V" single peak curves. The temperatures were low in the morning and evening, which was high in the afternoon at about 16:00. The main reason is that the study area is located in the south, and the sunshine period is longer in spring. So that the endothermic and exothermic reached the balance at 16:00, when the temperature was the highest. It also found that the temperature of grassland is the lowest, while the temperature of the concrete road (direct sunlight) is the highest. The temperature of the concrete road under the shadow is lower than that of the concrete road with direct sunlight. The temperature difference between them is about 1℃. Because tree canopy tends to reduce surface temperature in the shade and thus reduces storage and convection of heat. Shading by trees can remove a large amount of incoming short wave radiation by reflection and transmission through their leaves. Therefore, the surface and air temperature can be lower in the shade of trees than in surrounding unshaded areas. So one way to mitigate urban heat island thereby reduce human heat stress is to increase vegetation cover in urban areas as vegetation can provide evatranspiration cooling and shading benefits as well as other ecosystem services.

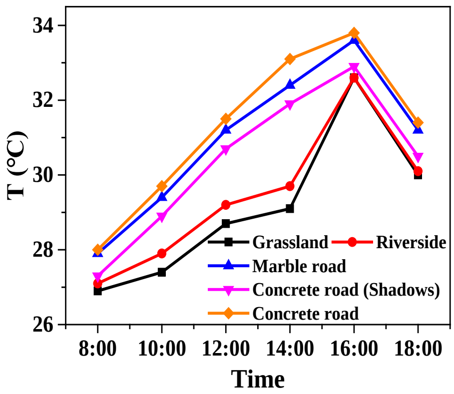

Fig. 5 Daily variation of temperature at different underlying surfaces.

4.2 Daily Variation of Relative Humidity at Different Underlying Surfaces

As shown in Figure 6, the highest values of air relative humidity for five different underlying surfaces all appeared at 10:00, while the lowest values appeared at 16:00. Trees release water vapour to the air from leaf stomata during photosynthesis, which is known as transpiration. Leaf transpiration and soil water evaporation are all contributed to the air humidity. The relative humidity of the air changed at the beginning of 8:00 in the morning. It risen first, then dropped, and finally continued to rise following the sine curve. Although the trend of the curve changes in the same trend, there are obvious differences in the influence of the different underlying surfaces on relative humidity. For example, the relative humidity of hardened roads were lower than those at the riverside and the grassland.

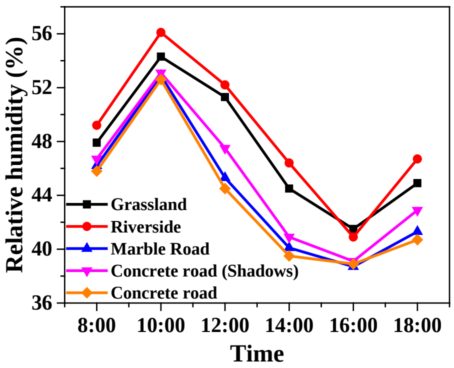

Fig. 6 Daily variation of relative humidity at different underlying surfaces

4.3 The Relationship between Temperature and Relative Humidity

The temperatures and relative humidity of different underlying surfaces were numerical averaged. As shown in Figure 7, the peak temperature was at 16:00, when the relative humidity was at the lowest level. It is because that in the morning, the temperature and the relative humidity of the air rise with the increase of the solar radiation. After that, the temperature of the air continues to rise due to persistent solar radiation, while the relative humidity of the air decreases gradually and reaches a critical point at 16:00. Then, the radiation of sun weakened and the temperature began to decrease, while the relative humidity of the air gradually rose. According to the results, the temperature is negatively related to the relative humidity. Transpiration can mediate latent heat loss during the conversion of liquid water to vapour, thereby resulting in the cooling of the leaf and the surrounding environment.

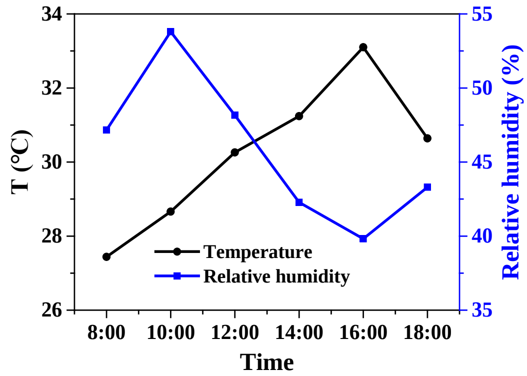

Fig. 7 Daily variation of mean temperature and mean relative humidity.

5. CONCLUSION

In this work, the outdoor temperature, relative humidity and other environmental parameters of Jiangsu University campus were tested. GIS technology was used to study the distribution characteristics of campus thermal environment and the influences of different underlying surfaces on campus thermal environment.

According to the temperature spatial distribution map of Jiangsu University, the distance between the low and the high temperature region were about 300m ~ 600m and the temperature difference was 1°C. So that the heat island effect is more obvious.

The daily variation of the temperature of five different underlying surfaces showed inverted "V" single peak curves. The temperature was low in the morning and evening and high in the afternoon. At 14:00, the temperature difference between the grassland and the concrete road (direct sunlight) was about 4°C.

The temperature and the relative humidity showed a trend that the temperature was rising while the relative humidity was decreasing obviously. The temperature was negatively correlated with the relative humidity.

The temperature of concrete road with direct sunlight was obviously higher than that of concrete road with shadow, and the temperature difference between them was about 1°C. It means that trees play an important role in regulating the temperature.

The temperature is higher with abundant of population and traffic, such as canteens, playgrounds and bathrooms.

6. OUTLOOK

According to the conclusions, we forward five specific suggestions for improving the outdoor thermal environment in Jiangsu University:

The protection of the existing grassland is an effective way to mitigate the heat island effect. Therefore, the management system of campus vegetation should be perfected as soon as possible.

Recently, our school is on the remediation of the Yudai River Basin. Widening the river channel and increasing the drainage area could effectively reduce the outdoor temperature of the campus.

In summer, the temperature in the places with a small number of vegetation coverage and lots of people, such as the library is high. Sprinkling water could be used to increase the humidity of the air and decrease the temperature, which can provide a comfortable learning environment for students.

Tall shrubs should be planted in the areas with direct sunlight, which can increase the shadow area, and thus effectively decrease the temperature.

Students should be encouraged to instill the idea of environmental protection into all aspects of daily life. This is a long-term and meaningful work, which can directly reduce the anthropogenic heat emission and weaken the campus heat island effect.

7. ACKNOWLEDGEMENTS

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