The Study on Microclimate Simulation of Country Park Based on ENVI-met Software ——Take the East Gate Entrance Area of Guangdong Tianlu Lake Country Park for Example

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Abstract. At present, the outdoor thermal environment research methods mainly include two types: the measurement and simulation, the limitation of the field measurement only makes an objective record and reflect on the existing environment of microclimate, it can't make predictions; while the software whether can simulate thermal environment of the scene or environment to make quantitative predictions, to make up for any deficiencies in the study of the measured is a concern. ENVI - met is considered to be the best fluid mechanics simulation software of the outdoor thermal environment, which is mainly in the application of high latitude and cold regions. Based on the research of subtropical country park outside environment thermal comfort, this paper analyzed three seasons of climate data through the experimental research of the east gate entrance area of Guangdong Tianlu Lake Country Park for spring, summer, autumn; and combined with simulation software ENVI-met to build the model, respectively for spring, summer, autumn three season of simulation experiment, then the authors work out the comparative study of the measured and simulated data, and analyzed the change rule to find out the following four conclusions:(1) with the actual measurement of meteorological data as boundary conditions, ENVI-met can simulate microclimate condition of the subtropical hot and humid region country parks outdoor environment; the change trend of simulated data and measured data is identical within the scope of the instrument error.(2) compared with the simulated data and the measured data, it can more reflect the general trend of change, and is not affected by the measured specific emergency on that day.(3) the variations in the data of simulation generally less than the measured data.(4) the hard ground and artificial facilities compared natural tree shade field simulated results is more close to the actual measurement results. Thus this paper could confirm that the simulation software ENVI-met, which began in the high latitudes, is also could be used in the simulative study of subtropical hot and humid area of outdoor thermal environment, and as a aided designing tool; the authors preliminarily found a certain rule for the background parameter setting in the simulation experiment to set up a foundation for further research in the future.

Introduction

With the rapid development of urban construction, our country park has begun to enter a period of rapid development. Meanwhile with people's living standards improving, the country park as a part of urban green space, people's environmental requirements is increasing, its requirements of the comfort for microclimate outdoor environment is also increasing. This article is based on the subtropical Country Park outdoor thermal ambient comfort research, combined with the practice design cases in country parks for microclimate simulated data, hoping to check the simulation software ENVI-met whether apply to use in the subtropical hot and humid areas outdoor thermal environment simulation studies, exploring its feasibility in the auxiliary design and building foundation for simulation experiments of the research related to the ideal model in country parks.

Study Overview and Ideas

Overview of the outdoor thermal environment

At present, measurement and simulation methods are mainly two categories in the outdoor thermal environment, measurement including ground measure, infrared remote sensing, aerial photography and so on; simulation including experimental simulation, mathematical models simulation and computer software simulation methods.

In the field survey study, Bonan[1] through a test of a residential in Colorado found the arrangement of lawns and residential density is also affected on the community micro-climate; Chen Yu etc.[2], respectively, measured Singapore Bukit Batok National Park and Clementi Woods Park as well as its air temperature and humidity of the surrounding; Research of Ca [3], etc. did in tokyo are also described; Al Hemiddi[4]measured different green spaces' annual surface temperature and ground air temperature at 1.5 meters at Los Angeles (UCLA) campus in California University. Ground measure is the primary means of research on building environment microclimate, its limit is only making an objective record and reflecting already exists on the micro-climate environment, but can't make a pre-judgment for it. Moreover, in the current measurement study, we more concerne about the micro-climate in summer, while the rest of four season are concerned about in the actual research is rare; less subtropical hot and humid regions for the measured study in Country Park outdoor thermal environment.

In the computer software simulation, there are some research results at home and abroad, but mainly for physics environment research of the residential outdoor space. Architecture Environment Joint Laboratory has done some work in this respect, such as: using of improved CTTC (Cluster Thermal Time Constant) model combined with CFD (Computational Fluid Dynamics) simulation method, considering the solar radiation, green measures and architectural layout affect the thermal environment, predicting and evaluating of residential quarters in different regions and gives the evaluation index[5]. In the simulation micro-climate research of residential area, Li Xiaofeng[6] took CFD simulation model, outdoor radiation calculations, combined calculation method as research objects, established of a hierarchical simulation system. Lin Bo Rong[7] established a common outdoor thermal environment simulation system under green conditions, and combined with the actual measurement results which are verified. Germany Michael Bruse and Heribert Fleer (1998) in Ruhr Bochum University use ENVI-met simulation analysis of the local urban planning changes (such as trees, lawns and new buildings) under different conditions on the mesoscale brought microclimate effects [8]. The numerical simulation software simulated to the interactions between small scale urban space within the ground, plant, architecture and atmosphere of dynamic[9]. Since the establishment simulation model and its background conditional is currently unable to meet fully synchronized with the actual situation, the simulation software can whether make a quantifiable anticipation for the scene or the thermal environment, then make up the actual research is the lack of concern.

ENVI-met is considered to be the best fluid mechanics simulation software in the field of an outdoor thermal environment research [10], the main application began in cold areas of mid and high latitudes. South China University of Technology, State Key Laboratory of Subtropical Architect Science Building Energy Conservation Center has begun to explore the software used in the relevant studies (Chen Zhuolun, Yang Hill et al.) [9,10,11] of subtropical hot and humid regions, the study of this paper is carried out on this basis. In this study, we use German ENVI-met simulation software of small-scale three-dimensional climate for the outdoor thermal environment simulation in the subtropical country parks, and combined with the measured data for comparison analysis to explore the applicability of this software in the subtropical humid areas' study, and summarize relevant microclimate effects on the country park landscape design factor.

Research Ideas

Research ideas in this paper is under a certain simulated background conditions setting, we conducted micro-climate modeling in main entrance area of Guangdong Tianlu Lake Country Park in spring, summer, autumn, combined with spring, summer, autumn scene measured data, compared and analysis of changing rule of simulated and measured temperature and related influencing factors;

check ENVI-met simulation software whether apply to modify the subject of further study for the foundation work outdoor thermal environment of Country Park in hot and humid subtropical regions.

Model and background conditions setting

Research object

We select east gate entrance area of Tianlu Lake Country Park in Guangdong, which is located in planning area, northeast Luogang district, 880 hectares. Its latitude and longitude is 113 ° 8'51 "E - 113 ° 11'7" E, 23 ° 12'35 "N - 23 ° 14'26" N, which is in the subtropical climate zone.

Simulation area is mainly located in east gate entrance and parking area near the highway square of Tianlu Lake Forest Country Park. There are arranged five measuring points in this area. The position of the measuring point, shaded, underlying surface conditions and test parameters are shown in Table 1 and Figure 2.

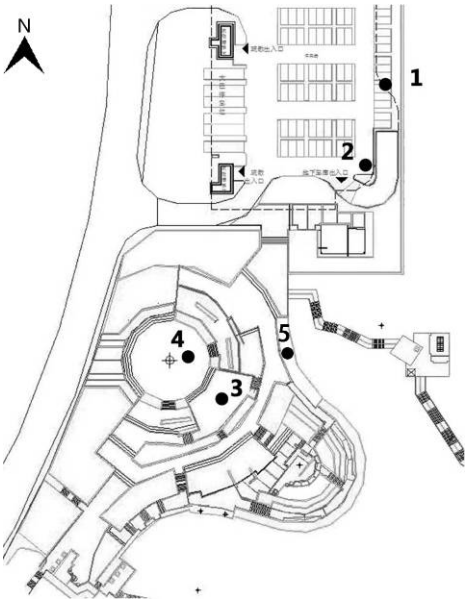

Fig.1 Distribution diagram for measurement and simulation of the east gate entrance area in Tianlu Lake Country Park

Table 1 Distribution diagram for measurement and simulation of the east gate entrance area in Tianlu Lake Country Park

	Location		Shade conditions	Underlying	Test Parameters
1	East gate squre	Parking lot	shade of tree	Planting grass brick	T,RH,W
2		Parking lot	Exposure	concrete	T,RH,W
3		Cable membrane	Under the cable membrane	wooden floor	T,RH,W
4		Circular sinking square	Exposure	square brick	T,RH,W
5		Circular plazas lotus pond	shade of tree	grass	T,RH,W

Note: T is the air temperature, RH is relative humidity, W is the wind speed.
(This article mainly discusses air temperature T)

a) Point 1: parking lot, planting grass, brick under tree	b) Point 2: parking lot, exposure, concrete pavement	c) Point 3: cable membrane	d) Point 4: square, exposure area	e) Point 5: lotus pond, under the tree

Fig.2 Measuring points arrangement of the east gate entrance area in Tianlu Lake Country Park

Reasearch group respectively in spring on April 10, 2011, summer on August 14, 2011and autumn on November 6, 2011 to conduct research and measurement data, the weather is sunny and cloudy in that day. Measured data including 1.5meters height of air temperature, black ball temperature, humidity, wind speed, this paper mainly studies the air temperature. The description of the using measured instrument is shown in table2.

Table 2 Introduction of instrument

Measuring instrument	Model	Measuring content	Range	Precision instruments	Sampling frequency
Air temperature and humidity recording device	HOBO Pro V2 U23，Origin: the United States	Air temperature, Relative humidity	-40~70° C,0~100 %	±0.02°C（0~50°C） ±2.5%（10~90%）	1 minute (automatic)
Thermal anemometer ball	QDF-6,Origin: China	Wind speed	0~30m/s	±3%（full scale）	30 minutes (manual）
Black ball temperature recording instrument	GL-2000，Origin: Japan	Black ball temperature	20~120° C	±0.5°C(20~50°C)±1° C(50~120°C)	1 minute (automatic)

Physical Model Setting

In order to ensure the boundary conditions of simulated target areas closer to the real scene, the simulated range includes a larger area than the measurement area, 240m × 320m (Fig. 3,4). Model size is 240 m × 320 m × 40 m, a resolution of 1 m × 1 m × 1 m. Core area are east gate parking and square close to the highway; there are five measuring points arranged in the region(Figure 1).

Fig.3 Simulative plane view for ENVI-met model of the east gate entrance area in Tianlu Lake Country Park

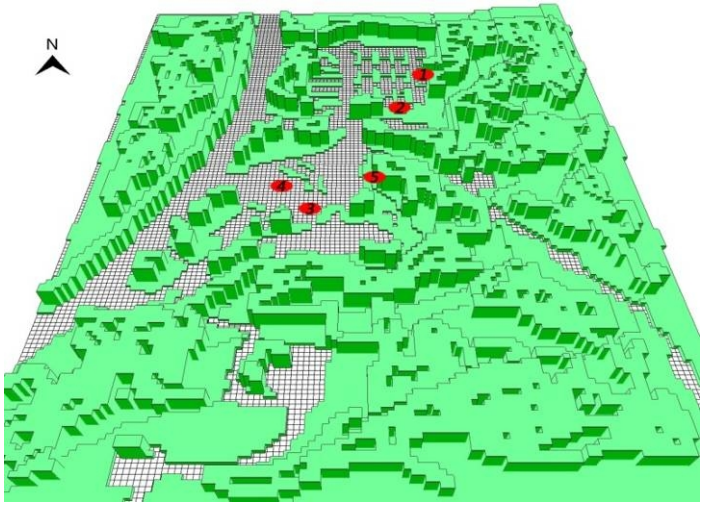

Fig.4 Simulative three-dimensional view for ENVI-met model of the east gate

Model record air temperature, humidity, wind speed, etc. hourly at a person's height position. Test time is 7:00 to 19:00, an hour record at a time; taking into account the recorded data is not accurate enough at first, simulation analysis chose the data at 9:00 to 17:00 coincide with the measured time.

Parameter Value Setting of background conditions set

In this simulation test, we explored parameter values of setting for the background conditions, respectively make a comparison for a site of three times measured and simulated data in spring, summer and autumn.

Table3 Simulated background condition value setting on spring,summer and autumn

Setting background factors influence	2011/04/10 Spring	2011/08/14 Summer	2011/11/06 Autumn	Parsing
W_{10}	2.16	1.35	1.62	Wind Speed in 10 m ab. Ground [m/s] in spring
T	295.34	301.21	298.06	Initial Temperature Atmosphere [K] in spring
RH	60.15	65.2	64.12	Relative Humidity in 2m [%] in spring

Every time we use the measured meteorological data on that day as background condition. We set to Guangzhou area in this test condition, identified of latitude and longitude in this region to determine its position of the sun and solar radiation intensity. Software automatic calculated the meteorological data such as solar radiation and scattering of radiation [12]. Simulation time is 6:00 to

18:00, a total of 12 hours, every half an hour record at a time, considering the initial simulation time is not stable, so the simulation data analysis use the data from 9:30 to 17:30.Setting the background conditions for the case of three measured values are shown in Table 3.

Measured and simulated result and analysis of data

Measured Results and Analysis Of Data

From spring measured data(Fig.5),we can observed five measuring points' temperature range of measured data between 22˚C to 34˚Cin the spring, more fluctuation, temperature of measuring point 2 exposure under in concrete pavement with a highest value and fluctuate in widest rang, measuring point 5 parterre in the shade with a lowest temperature value. Five measuring points average temperature can be observed no longer begin to rise in 16:00, presented a gradual decrease. Among them, effect of plant shade to reduce the temperature is obvious, such as parterre in the shade (measuring point 5) compared with the exposure under concrete pavement (measuring point 2), can effectively reduce the temperature; especially 1:00 in the afternoon, the air temperature difference at a maximum value, reach about 5 ˚C.

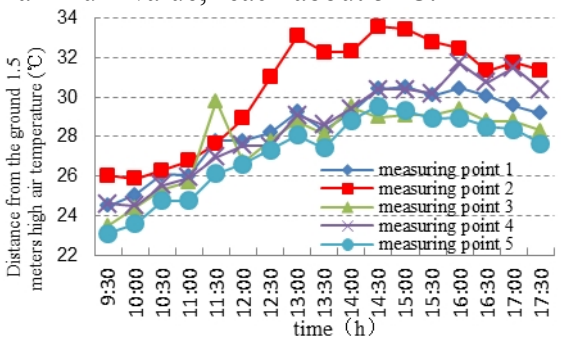

Fig.5 The Comparison ofmeasured temperature data changes in spring

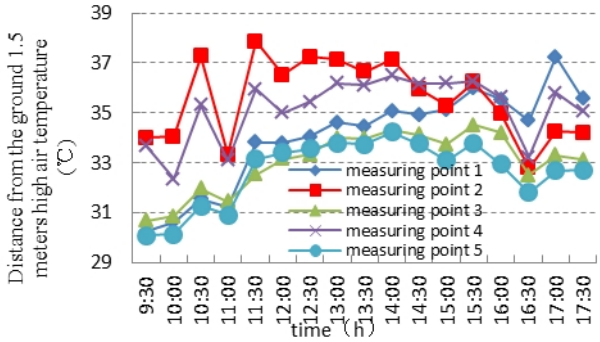

Fig.6 The Comparison of measured temperature data changes in summer

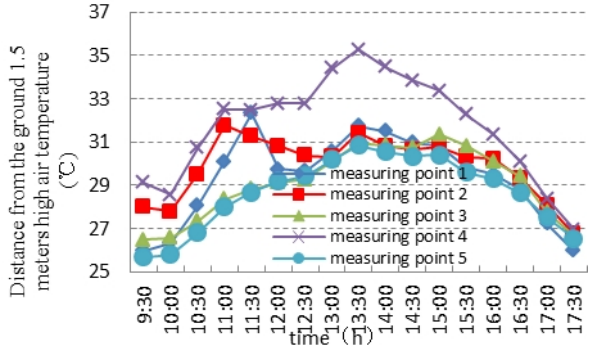

Fig.7 The Comparison of measured temperature data changes in autumn

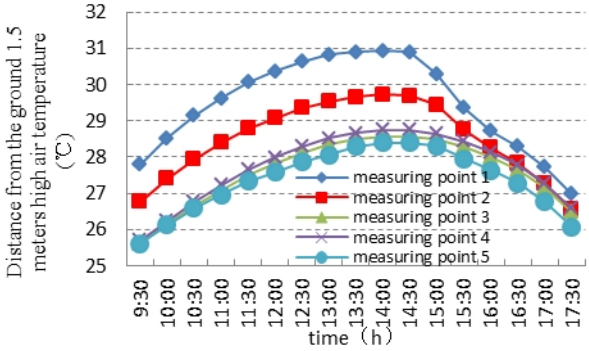

Fig.8 The Comparison of simulated temperature data changes in spring

From summer measured data (Fig.6), we can observed five measuring points' temperature range of measured data between 29˚C to 38˚C, and changes in large fluctuations; the day of 11:00 and 16:30 or so under a shower, so the temperature has dropped. Among them, the temperature of measuring point 2 and 4 are higher than measuring point 3 and 5. As can be seen from the measured data, plants shade and artificial shade can effectively reduce the outdoor ambient air temperature. Especially in the day of half past eleven, maximum cooling effect of shade is about 5˚C.

From autumn measured data (Fig. 7), we can observed five measuring points' temperature range of measured data between 25˚C to 36˚C in the autumn, more volatile changes in temperature. Measuring point 4 with a highest value and volatility changes the biggest, measuring point 5 with a lowest temperature value. Five measuring points can be observed in a day temperature have reached the highest value at 1:30p.m. In the autumn, the cooling effect of artificial and plant is equally clear, maximum cooling effects of shade is about 4.5 ˚C.

Measured data in spring, summer and autumn three seasons reflects consistent with weather changes in that day. Among five measuring points, measured temperature in summer changes most in

volatility, measuring point 1, 3 and 5 fluctuations of temperature are smaller than point 2 and 4. Measured data reflect the temperature in the shade is more suitable, the temperature under exposure changes in volatility with high temperature. Measured data show that in the spring, summer and autumn, the highest temperature of the country park in entrance area is more than 34˚C, summer is even reached 38˚C, it is necessary to combine landscape design and visitors activities to take necessary measures in outdoor shade (collectively called"landscape shade"); at the same time, in the venue, the landscape design factors such as artificial and plant shading compared to exposure from the pavement without shade design can effectively reduce the temperature in the spring, summer and autumn, the artificial and plant shading maximum cooling effects is about 4.5~5˚C, and the site under shade condition on a small fluctuations in temperature changes, it can provide a more comfortable environment for tourists.

Simulation results and analysis of data

From spring simulated data (Fig. 8), we can observe the temperature of five measuring points simulated data range between 25˚C-31˚C in the spring, significant variation in which measuring point 1 in shade under the grass brick is the highest temperature value and changes in a largest fluctuation, measuring point 5 in the shade of the parterre at lowest temperature value. Five measuring points can be observed the temperature in both reached highest value in a day after 2:00p.m. Among them, the cable under the membrane (measuring point 3) and parterre under the shade (measuring point 5) can effectively reduce the temperature. In the simulation, the maximum cooling effect of shade is about 2.57 ˚C.

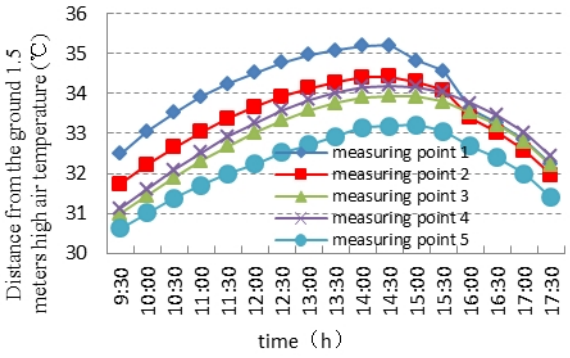

Fig.9 The Comparison of simulated temperature data changes in summer

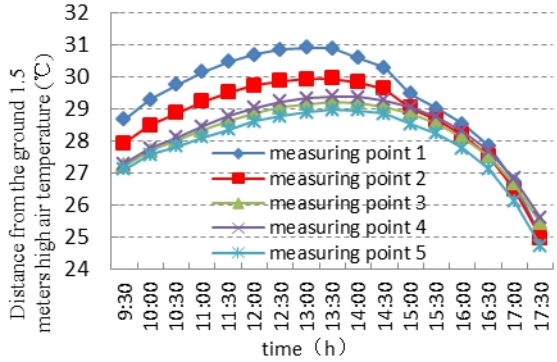

Fig.10 The Comparison ofsimulated temperature data changes in autumn

From the summer of simulated data (Figure 9), we can observe 5 points' temperature range between 30˚C-36˚C, significant variation in which measuring point 1 in the shade under the grass brick with a highest value and the changes in largest temperature fluctuations, measuring point 3 and measuring point 5 with a minimum temperature value. Five measuring points can be observed in a day temperature reached the highest value after 2:00p.m. We can see the landscape shading (including artificial and plant shade) can effectively reduce the temperature; maximum cooling effect of artificial shade is about 1.63˚C, the maximum cooling effects of plant is about 2 ˚C.

From autumn simulated data (Figure 10), we can observe five points temperature range between 24˚C-31˚C, variation evident in the shade of a measuring point where the grass brick under the highest value and the changes in temperature fluctuations largest, measuring point 3 has the lowest temperature values at the cable film. Five measuring points can be observed in a day temperatures have reached the highest value at 1:30 p.m. Among them, the landscape shading (including artificial shade and plant) can effectively reduce the temperature; cooling effect of shade maximum is about 1.84 ˚C.

Simulated and measured data comparative analysis

To further investigate the correlation degree between simulated and measured data, the author analyze simulated and measured temperature value of each measuring point in spring, summer and autumn.

Simulated temperature trends coincide with the measured one

As can be seen from the comparison (Fig. 11,12,13,14,15),compared with measured one each simulating point's value have some error in spring, summer and autumn, but the overall trend of a day is more consistent. Measured temperature values fluctuate widely, simulated temperature values is more gentle. Among them, the simulated data trends in summer relatively close to measured data. This validate the ENVI-met software used in the simulation of the outdoor thermal environment in subtropical Country Park and related evaluation is feasible.

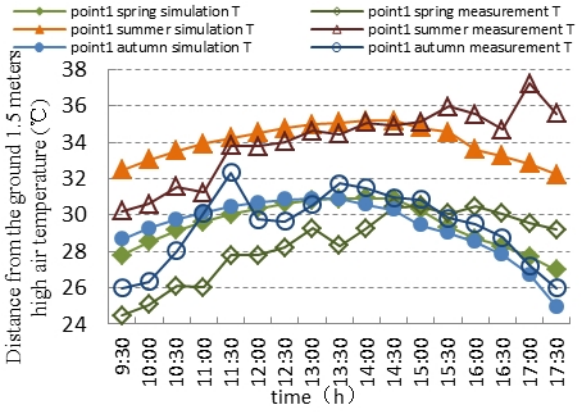

Fig.11 A comparisonof simulative and measured temperature changes of measuring point one in spring, summer and autumn

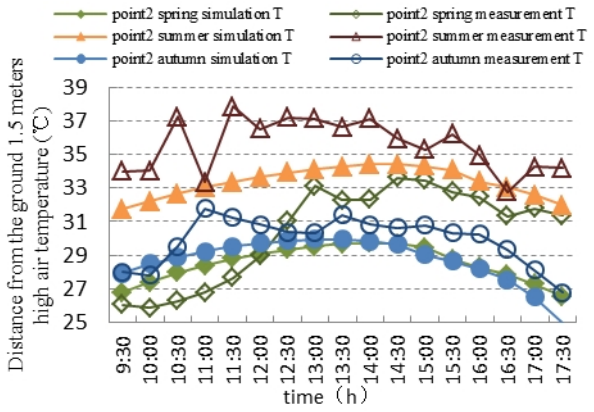

Fig.12 A comparison of simulative and measured temperature changes of measuring point two in spring, summer and autumn

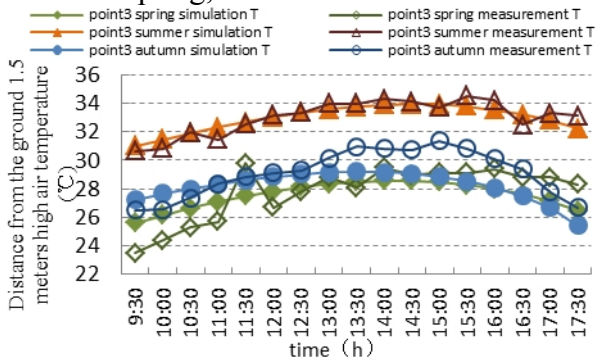

Fig.13 A comparison of simulative and measured temperature changes of measuring point three in spring, summer and autumn

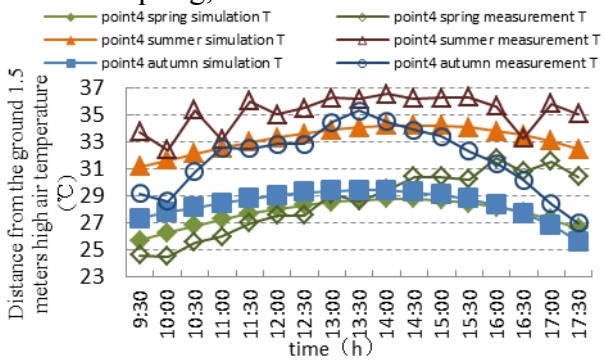

Fig.14 A comparison of simulative and measured temperature changes of measuring point four in spring, summer and autumn

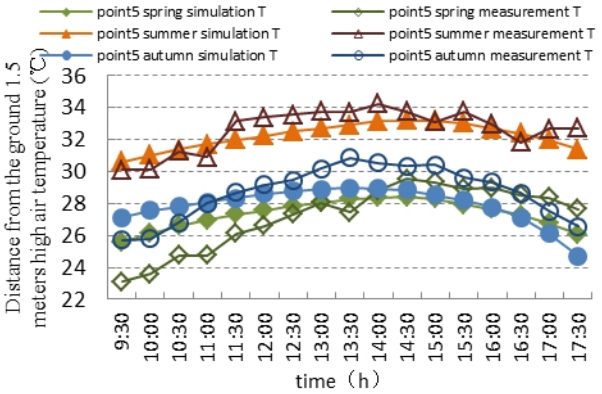

Fig.15 A comparison of simulative and measured temperature changes of measuring point five in spring, summer and autumn

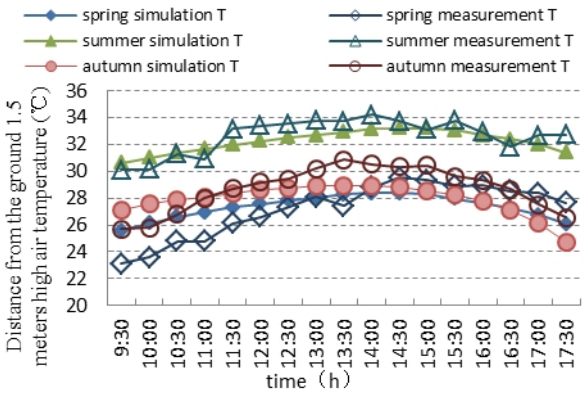

Fig.16 A comparison of simulative and measured temperature changes of measuring point three in spring,summer and autumn

In landscape design factors, plant shade and artificial shade could play a certain extent on cooling effect, such as the temperature value of summer in the simulation experiment reduce to 2.5˚C, and the temperature value decrease in the actual measurement up to 5˚C. This indicates that through the simulation software, plant shade and artificial shade may to some extent reflect the actual design effect; it also shows that the software can be used as an auxiliary tool for landscape design.

The degree of influence on different landscape factors to the outdoor thermal environment in measurement and simulation is more consistent

Through spring, summer and autumn measurement and simulation of the comparative analysis (Tab.4), can be found different landscape factors on outdoor thermal environment have different degree of influence in the measured and simulation.

Table 4 Ranking Table of average temperature value in spring, summer and autumn

Average temperature value rank	①		②		③		④		⑤
Spring measure	point 2	>	point 4	>	point 1	>	point 3	>	point 5
Spring simulate	point 1	>	point 2	>	point 4	>	point 3	>	point 5
Summer measure	point 2	>	point 4	>	point 1	>	point 3	>	point 5
Summer simulate	point 1	>	point 2	>	point 4	>	point 3	>	point 5
Autumn measure	point 4	>	point 2	>	point 1	>	point 3	>	point 5
Autumn simulate	point 1	>	point 2	>	point 4	>	point 3	>	point 5

We synthesis contrastive analysis of the degree of influence on different landscape factors to the outdoor thermal environment in spring, summer and autumn three seasons measuring and simulating. We observed that spring, summer, autumn measurement and simulation situations are basically the same, in the case of measuring point exposure to air temperature is higher than where have shade sheltered situation; measuring point 5 in the shade of plant condition has lowest temperature, temperature of measuring point 3 in cable-membrane shade followed, it explains that shade can effectively reduce the ambient air temperature.

Measured temperature fluctuations in spring, summer, autumn are actually more obvious, the highest temperature, fluctuations largest are measuring point2 exposure in concrete pavement and measuring point 4 exposure under hard paving stone.

Simulating software more suitable for simulation of landscape shade design factor

Through the difference values between simulated and measured data in spring, summer and autumn (Fig.16). We can observe the difference values of measuring point 3 simulating data in three simulations compared with measurement is lowest, and therefore we can infer that preliminary simulation software more suitable for artificial landscape design, especially some of the artificial landscape of facilities (such as a hard square, cable film) designs. Analysis of the reasons is under natural conditions, tree planting has become a relatively stable microclimate, and in the software simulation, consider a single variable, except the complicated factors.

Comparison of the different values between simulated data and measured data

Based on a comprehensive comparison analysis of spring, summer, autumn three simulation experience analysis, the difference values of three simulation results and experimental results are closer(Table5); the results show that the value in the case of reasonable definition of background conditions, ENVI-met software is suitable for the outdoor thermal environment simulation of the Country Park in subtropical hot and humid areas.

Table 5 Difference comparison of simulative and measured data in spring, summer, autumn

Measuring point	Situation analysis	Average Difference		
		Spring	**Summer**	**Autumn**
1	Under tree planting grass brick	1.09	0.06	-0.01
2	Exposure of concrete pavement	-1.92	-2.04	-1.21
3	Under cable membrane	-0.19	-0.05	-0.9
4	Exposure hard stone floor	-0.8	-1.83	-3.37
5	Hard paving stone under tree	0.19	-0.38	-0.77
Total average difference		-0.326	-0.848	-1.252

Conclusions

The micro-climate simulating and measuring comparative study of east gate entrance area of Tianlu Lake Country Park in Guangdong may initially get the following conclusions:

(1) Using the actual measured meteorological data as a boundary condition, ENVI-met can simulate the micro-climatic conditions of Country Park outdoor environment in subtropical hot and humid regions. Within the error range of the instrument, the simulated results of temperature change trend and measured value are basically consistent.

(2) Simulated data compared with measured data, is better to reflect changes in the general trend than not affected by specific emergency on that measured day.

(3) From the view of data different values, using the actual measured value of that day for background conditions, simulated data of the simulation software can reflect the actual situation in a certain extent, the change range is generally less than measured data.

(4) From the point view of field trial scope, hard ground and artificial facility shade site compared to the results of the simulation under natural trees shade is closer to the actual measured result.

Rethinking and optimization suggestion

Background conditions setting in simulation experiment has an important influence on the success of simulation experiment. The author in order to seek appropriate simulation background conditions, carried out several simulation experiment and comparison; the final selection of this simulated background condition is closest to measured conditions, and the difference values between the simulation results and measured data is also minimized. Of course, the difference between the simulated and the measured data is influenced by instrument accuracy and the observed meteorological conditions on that day, there exists particularity and contingency, the data can't represent the whole summer data. Meanwhile, there still exists some need to be further optimized part in the simulation experiment, it including:

(1) In the model, the specific definition is just outside east gate entrance area and the local environment, while the actual surrounding environment even a broader range should be considered because nature is a whole, its environment is more complex and more changeable. Simulation software showed only a part of it, and the simulation software consider of a single variable and removing the complicated factors.

(2) In the simulation software model, the model is only used to establish the tree defines 10 meters high deciduous and other conditions. However, in the actual environment, different shade plants have different effects, especially in the different regions, species differences become more obvious.

(3) Due to restrictions by software modeling conditions, environmental factors of measuring point 1 under the shade of grass could not be precisely defined in the model, only consider a single variable of the tree, so there is a certain bias between simulation results and experimental results in a certain degree.

(4) In the actual measurement, we only measured 1.5 meters high wind speed, and then calculated 10 meters high wind speed through the wind profile equation. In future measurements, if we could directly measured 10 meters high wind speed, it will help to improve the accuracy of the simulation.

Through this comparative study of east gate entrance area in Guangdong Tianlu lake Country Park in spring, summer and autumn microclimate simulation and measurement, the author check the ENVI-met software simulation can be used in outdoor thermal environment of Country Park which is in subtropical hot and humid regions, and it has assisted analysis in landscape design. It has laid a solid foundation for further study related topics adaptive design strategies based on subtropical hot and humid climate and future design practices.

(Source: All the tables and figures were provided by the authors.)

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