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論 文 内 容 要 旨

1. Introduction

The urbanization has led to many issues in cities, and these problems have been becoming more and more serious due to their effects on thermal comfort and environment, people's health and resource degradation. Global Warming and Urban Heat Island (UHI) have become main problems all of the world, and the environmental degradation results in not only the increase of energy consumption in cities but also healthy problem of people.

In this study, the impact of urban planning on urban climate in Wuhan city was studied (Fig. 1). Wuhan is a typical city in humid subtropical climate city, China, and is the capital of Hubei Province, People's Republic of China, located at 113°41′-115°05′ East, 29°58′-31°22′ North. Because of its hot summer weather, Wuhan is commonly known as one of the Three Furnaces of China, along with Nanjing and Chongqing. Spring and autumn are generally mild, while winter is cold with occasional snow. The monthly 24-hour average temperature ranges from 3.7°C in January to 28.7°C in July. Annual precipitation totals 1269 millimeters, mainly from May to July; the annual mean temperature is 16.63°C, the frost-free period lasts 211 to 272 days and the annual sunlight duration is 1810 to 2100 hours. Extreme temperatures have ranged from −18.1 °C to 42.0°C.

Fig. 1 Location of Wuhan

In recent years, owing to rapid urbanization in developing countries and the various environmental problems in urban areas, such as air pollution, heat islands, and energy consumption, the urban outdoor environment has received considerable attention over the years. Many studies on urban climate have been carried out, such as field measurement, simulation and wind tunnel experiment, etc. Accompanying with the development of simulation techniques, many researches regarding to simulation combined with wind velocity, air temperature, humidity and radiation were carried out.

Most studies of microphysics and boundary-layer schemes have been confined to coastal cities and northwest areas with few considering the Humid Subtropical Climate city in China.

Zhou (Huangzhong University of Science and Technology) researched on 3 scenarios with different water areas in built-up zone of Wuhan in summer period. But it only considered the land use conditions changed (water area change), did not consider the impact of urbanization (building density, green area ratio) on urban climate.

Overall, the following two aspects were studied in this thesis:

1) appropriate microphysics and boundary-layer schemes for use in the WRF model for simulating the urban climate in Wuhan city, China.
2) the influence of building density and green area ratio on urban climate (air temperature, wind velocity, heat island).

2. Thesis structure

The thesis is divided into five chapters.

Chapter 1: The introduction of research background (global warming and urban heat island), previous research on urban heat island, urban canopy model and green coverage ratio, the objectives and the structure of the thesis are given in Chapter 1.

Chapter 2: Chapter 2 aims at researching the appropriate schemes of microphysics and boundary-layer in WRF model for simulating the urban climate in humid subtropical climate city. Firstly, a field measurement was carried out in Wuhan, and the air temperature and relative humidity were recorded above building canopy layer. Secondly, the near-surface air temperatures (2 m), relative humidity (2 m) and wind velocities (10 m) from simulated data and observed data at two meteorological observatories were compared.

Chapter 3: The purpose is to explore the effect of different building densities on the urban climate in Wuhan city. In order to achieve this goal, 15 cases were designed with different building densities. Then, the effects of different building densities on urban climate were discussed through air temperature, wind velocity.

Chapter 4: The purpose is to explore the effect of different green area ratio on the urban climate in Wuhan city. In order to achieve this goal, 12 cases were designed with different green area ratio. The effects of different green area ratio on urban climate were discussed through air temperature, wind velocity.

Chapter 5: Conclusions of the thesis are highlighted and future works are discussed in Chapter 5.

3. Conclusions and future work

(1) The suitability of the microphysics and boundary-layer schemes in the WRF model for simulating urban climate in Wuhan was examined and the following conclusions were drawn:

1) Simulated results from four different combinations of microphysics and boundary-layer schemes (WSM3-MYJ, WSM3-YSU, WSM6-MYJ, and WSM6-YSU) were compared with field measurement results. The measured and simulated data were consistent with regard to trend. The results indicated that the WSM6-YSU model showed the best agreement with the measured data obtained in Wuhan city.

2) The applicability of the appropriate model was validated against near-surface air temperature, relative humidity, and wind velocity observations from two meteorological stations. The use of the WSM6 and YSU schemes in the WRF model meant that air temperature and relative humidity were well predicted, whereas the simulated value of wind velocity was not so accurate.

(2) The impact of building density on urban climate in Wuhan city was discussed, and the following conclusions were drawn:

1) In business zones, the influence of different building density on air temperature is greater than other zones. In the residential zone and industrial zone, different building density has less effect on air temperature during the daytime, and more effect in the nighttime.

2) In business zones, the air temperature decreases when building density increases; but when the building density equals to 50%, the air temperature increases with building density (Fig. 2).

3) In the residential zone, the air temperature decreases when building density increases; but when the building density equals to 40%, the air temperature increases with building density (Fig. 3).

4) In industrial zone, the turning point is 50%, when green area ratio equals to 20% and 30%. When green area ratio equals to 40%, the turning point is 40% (Fig. 4).

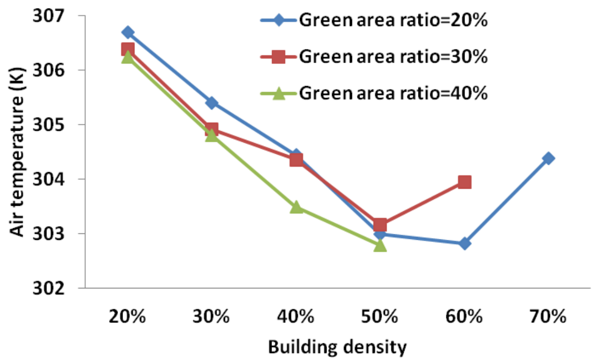

Fig. 2 The relationship of green area ratio and air temperature in business zone

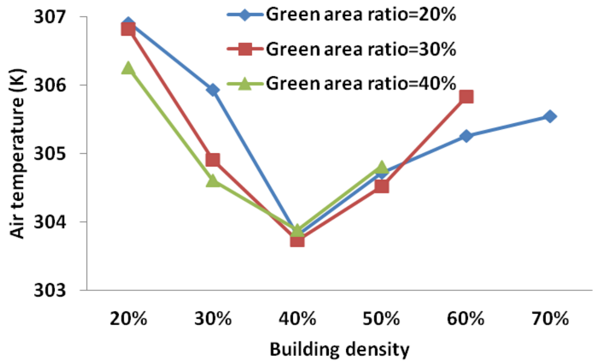

Fig. 3 The relationship of green area ratio and air temperature in residential zone

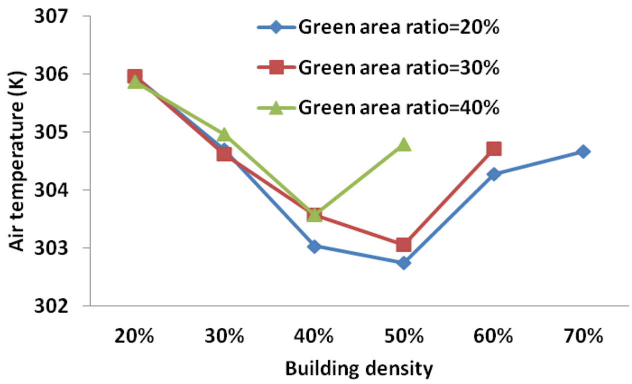

Fig. 4 The relationship of green area ratio and air temperature in industrial zone

(3) The impact of green area ratio on urban climate in Wuhan city was discussed, and the following conclusions can be drawn:

1) Different green area ratio has less effect on air temperature and wind velocity during the daytime, and more effect in the nighttime.

In business zone, whatever building density equals 20%, 30%, 40%, and 50%, the air temperature reaches maximum when green area ratio equals 30%. Before the green area ratio equals 30%, the air temperature increases with the green area ratio; after the green area ratio equals 30%, air temperature decreases when the green area ratio increases.

In residential zones, whatever building density equals 20%, 30%, 40%, and 50%, the air temperature reaches maximum when the green area ratio equals 30%. It is the same as air temperature in business zones.

In industrial zones, when building density equals 20%, and 30%, the air temperature reaches maximum when the green area ratio equals 30%. But when green area ratio equals 40%, the air temperature shows different change.

2) The changes in wind velocity are greater than temperature.

In business zone, when building density equals 20%, and 40%, the wind velocity decreases when the green area ratio increases. But when building density equals 30%, and 50%, wind velocity reaches maximum when the green area ratio equals 30%.

In residential zones, when building density equals 40%, and 50%, the wind velocity decreases when green area ratio increases. When building density equals 20%, wind velocity reaches maximum when the green area ratio equals 30%. But when building density equals 30%, the wind velocity shows large change; it increases when the green area ratio increases.

In industrial zones, whatever building density equals 20%, 30%, 40%, and 50%, the wind velocity reaches maximum when the green area ratio equals 30%.

(4) This study focuses on the influence of building density and green area ratio on air temperature and wind velocity in humid subtropical climate city. The study about adapting for the impacts of inevitable UHI will not stop. The future study of research on influence of urbanization and urban climate are as follows:

a) **Other humid subtropical climate city.** Wuhan city is the typical humid subtropical climate city in China, but what about the other humid subtropical climate cities, such as Malaysia, Philippines and so on. Studies on other humid subtropical climate cities are also needed.

b) **Heat balance and urban heat island influence.** This study only focuses on the air temperature and wind velocity, and did not discuss the heat balance, urban heat island influence and others, but these are very important in the urban climate, so, heat balance and urban heat island influence are also needed to research.

c) **The applicability of the UCM currently implemented in WRF for simulating the different building density green area ratio.** In chapter 4, the conclusions mean that the present UCM implemented in WRF is not suitable for simulating the different green area ratio. What the reason that can not suitable, how to improve it, how to improve the accuracy of simulation, there are also the important issue should be research in the future study.

論文審査結果の要旨

従来より、地球温暖化とヒートアイランド現象により大都市の温暖化が進行し大きな問題となっていたが、さらに近年は、極端気象の影響で外気温が体温を超えるような猛暑日が増加し、アジア諸都市において毎年最高気温を記録し、熱中症による死亡者数も増加している。本研究は、中国の代表的な内陸都市の武漢を対象として、領域気象モデルWRF (Weather Research and Forecasting model) を用いたメソ気候解析により、建物と緑地の密度が都市の温熱環境、風環境に及ぼす影響を分析したものである。

領域気象モデルWRFは、現在、様々な分野の研究者により利用されるようになりつつあるが、元々、気象学の研究者により開発されたものであり、都市部の土地利用や市街地形状が都市気候に及ぼす影響のモデル化に関しては改善すべき点が数多く残されている。特に、急速な都市化の渦中にあり、土地利用が短期間に大きく変化する中国の都市を対象とする場合、まず予測精度と適用限界を明らかにする必要がある。本研究では、2012年の9月に武漢において野外観測を実施し、このデータと解析条件を種々変化させたWRFの解析結果を比較し、大気境界層過程や雲微物理過程のサブモデルが解析結果に及ぼす影響を検討し、大気境界層過程のモデルとしてYSU スキーム、雲微物理過程のモデルとしてWSM6スキームを用いた結果が全体として測定結果と一番よく一致することを確認している。また地表付近の風速の再現に関しては、現在、広く用いられているUrban Canopy Model (UCM) には改善すべき点が残されていることも明らかにしている。

次に、上記の検討の中で最も観測結果との対応の良かった大気境界層過程と雲微物理過程のスキームを用いて、事務所ゾーン、住宅地ゾーン、工場ゾーンごとに建物密度を段階的に変化させた15ケースの解析、緑地率を同様に変化させた15ケースの解析を実施し、系統的な検討を加えている。そして、建物密度が低い場合は、建物密度の増加に伴う日射遮蔽の効果の増加により地表付近の気温は低下して行くが、ある建物密度の限界値（条件により変わるが概ね40%付近）を超えると、逆に密度の増加に伴って気温は増加すること、建物密度の変化が気温に及ぼす影響は、事務所ゾーンでは日中に顕著であるが、住宅ゾーンでは影響は主として夜間に現れること等を明らかにしている。

以上のように、本研究は、土地利用変化が急速に進む中国の大都市の都市環境計画への応用という観点から、現在幅広く利用されている領域気象モデルWRFの精度と適用限界を明らかにした上で、これを用いていくつかの興味深い知見を得ることに成功している。

よって、本論文は博士(工学)の学位論文として合格と認める。