Use of modified RAMS to simulate current and near future thermal Environment of ChongQing, China

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Abstract: Urban area is one of the most important spaces to the human beings. It contains the settlement of nearly half of the world's population and forms the center of social, political and economic activities. However, at the same time, urban area is facing the most serious environmental problems because it is the most remodeled area in the world. Urban heat island (UHI) phenomenon is one of the environmental problems caused by urbanization. It not only destroys the amenities of cities, but also increases cooling energy demand, degrades air quality and urban climate, and even plays the mischief with human health.

Meso-scale simulation is one of the various UHI researches being practiced today. It can analyze the regional urban climate of a city in question taking into account their meteorological interaction over the entire range to predict the overall effect. Hence it is often used in the simulations of UHI, especially in discussing the mitigation strategies of master plan. However, most of the widely used meso-scale models are based on hydrostatic equations which limited grid cell size, boundary layer approach, and accuracy degradation in vertical direction, etc. In addition, they do not have the special resolution to directly simulate the fluid dynamics and thermodynamics in the surface layer of urban areas; and the anthropogenic heat is also ignored though it may reach the order of solar radiation locally. Thus, it is essential to develop a high-accuracy comprehensive modeling system for the further understanding of UHI process and the inspecting of effective UHI mitigation strategies. Against these backgrounds, we couple a relatively high resolution non-hydrostatic meteorological model (RAMS, version 4.4) with a single layer urban canopy model (Kusaka, 2001), including anthropogenic heat into model, and analyzing the UHI condition of an inland mega-city - ChongQing, in China with the modified new model (RAMS-UC).

ChongQing is located in the southeastern part of Sichuan Basin and on the upper reaches of Yangtze River which is at the head of reservoir behind the Three Gorges Dam. In 1997, in order to develop the economics of western China as well as to coordinate the relocation of the immigrants from the Three Gorges Dam project area, the original ChongQing City was promoted to the status of Municipality. Thus, the current ChongQing municipality spreads a total area of 82,400 k m^2, and has more than 30 million populations. ChongQing is the beachhead for the development of the western part in China, massive construction and development works are currently under way in the city, for example, the constructed urban area in ChongQing is planned to extend from 350 km^2 to 820 km^2 in the coming 15 years, and urban population balloons from 5.2 million to 8.8 million, so there is a great chance that the UHI could become a serious problem in the near future in ChongQing. From a proactive standpoint, investigating current and forecasting future UHI situation can take on significance in developing ChongQing on a

sustainable way.

The UC model is integrated into the surface sub-model LEAF-2 (the Land Ecosystem Atmospheric Feedback model, Walko et al, 2000). After LEAF-2 divides the surface grid cell of RAMS into multiple sub-grid patches horizontally, the process of land use diagnosis is given. If the urban area ratio is larger than 0.9 percent in one grid cell, the UC model will be used in the surface calculating for the urban patch in that grid cell instead of LEAF-2 model.

The horizontal domain (grid1) size of ChongQing simulation is 1200km x 1200km consisted of 60 x 60 meshes. Inside it two nested grids are established, the coarser one spreads 240km x 240km and has the same number of meshes as grid1, the finest grid has a space of 80km x 80km which is divided into 80 x 80 cells. As this region is located in the transition zone between Tibet Plateau and the Sichuan Basin, its terrains are complex and undulating, the vertical domain is set from 50cm under ground to about 18,000m above sea level. The bottom atmospheric layer thickness of grid1 is 120m, and in comparison, that of two nested grids is 30m. In order to check the accuracy of model by comparing with ground observation results in ChongQing, the NCEP (National Centers for Environmental Prediction) Pressure Level Meteorological Data from 25th to 27th July 2001 are used as the input meteorological data of both current and future simulations, and both simulations continue 30 hours. The land use data for current simulation is extracted from Landsta-7 satellite image, and for future simulation is processed based on the 2020 Master Plan drawn up by ChongQing Planning Bureau.

The anthropogenic heat discharge is assumed being released from each artificial surface to the urban canopy air directly. Its intensity is estimated statistically from annual energy consumption in ChongQing in the current run. In the forecasting run, it is assumed that life style in ChongQing is upgraded to be similar to the current level in Tokyo, i.e. the heat discharge per unit surface of buildings and roads is similar to the value used in UHI researches for Tokyo.

Figure1 explains an instance of the simulations. Current temperature distribution (year 2001) is shown in Figure1-a. Figure1-b shows the forecast for temperature distribution at the year 2020. Comparing these two figures we can represent the difference in temperature distribution between these periods though Figure1-c.

The sensitivity between the models is tested by comparing the simulation results with observation data provided by Bureau of Meteorology in ChongQing. We found that, by integrating the UC model into RAMS, the average mismatch between the current simulation result and ground observation values is narrowed from 3.01 degree Celsius to 1.02 degree Celsius, thus proving that the modified RAMS-UC model overcomes the temperature underestimating problem of original RAMS.

The current and future simulation results indicate that, the high temperature areas expand largely with the expansion of urban areas. In the original urban setting, surrounding temperature at 2m aloft increases by a maximum value of 0.6 degree Celsius, while in the newly developed urban areas it shows an increase by around 5 degree. Thus the expansion of urban areas not only spreads the dimension of UHI, but also strengthens its intensity. Fortunately, two equilibrium mountain chains and crossed rivers inside ChongQing form natural green belts, hence preventing the sweep of high temperature areas and lightened UHI intensity in the inner-city districts to some extent. This also points us to the fact that, natural cooling system achieved through rational urban planning may mitigate UHI problems, and provide a sustainable urban development chance.

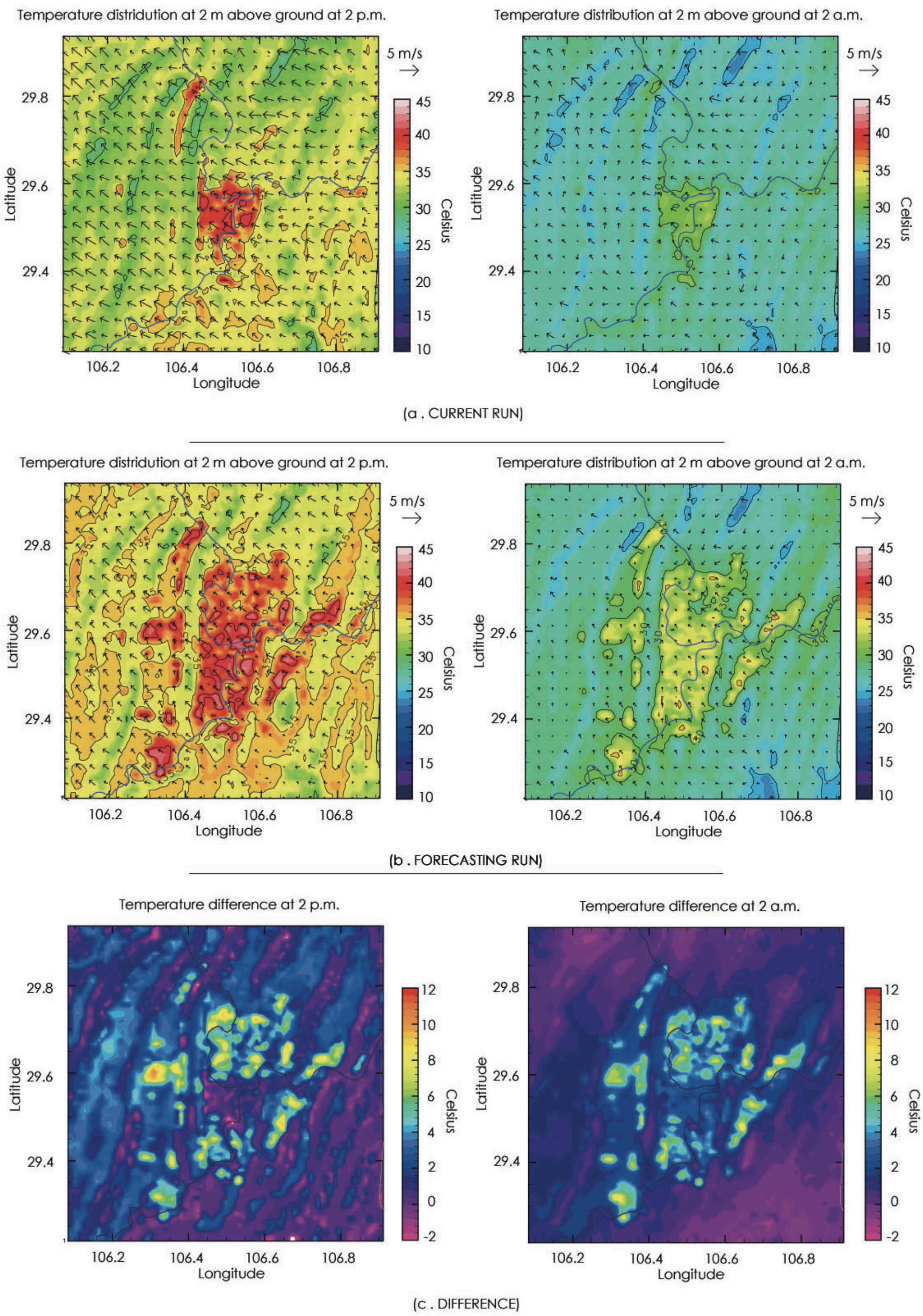

Figure 1 Simulation results