

Numerical experiments of the urbanization influence on the climate of Tokai area, Japan, using an urbanized mesoscale meteorological model

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1. Introduction

In order to investigate the urbanization influence on near surface temperature and energy fluxes, and to simulate the urban heat island (UHI) phenomena in Nagoya city of Tokai area, a numerical simulation is conducted by the PSU-NCAR mesoscale model MM5. As the standard MM5 is not capable to simulate the urban factors inside the PBL, an urban modification (Clarke 2005) is implemented by adding an anthropogenic heat flux term in the heat balance equation of MRF scheme and a sky view factor in the long wave radiation balance. Moreover, the single urban land-use type in USGS 24-category land-cover data is classified in three urban land-use categories using 30m resolution LADSAT +ETM satellite image by maximum likelihood method in Multispec to represent the inhomogeneous land-use pattern of Nagoya (Fig-1). Physical parameters of urban surfaces are also adjusted according to their surface properties.

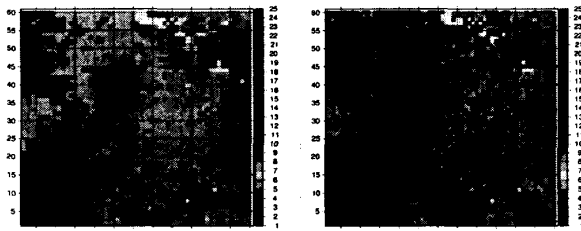


Figure 1. Land-use pattern in domain D3 (1km) by a) USGS 24-category (left); b) newly modified 24-category land-cover data (right).

A numerical simulation is performed by the standard and modified version of MM5 with two-way triple nested domains centered at Nagoya city during summer in August 2003. The gridded meteorological analyses data with 10 km resolution from JMA provides the initial and boundary conditions for mesoscale simulations. Three grid point locations are chosen in urban, suburban and rural area in the innermost domain D3 (1km) based on surface characteristics.

2. Results

In case of near surface temperature, the modified MM5 shows higher temperature environment [33°C-38°C] in urban area than the standard MM5 [30°C-34°C] because of anthropogenic heating, higher heat storage capacity and lower albedo of manmade surfaces. The modified MM5 shows considerable improvement in diurnal temperature cycle (average increase 3.2°C at day and 1.7°C at night) as shown in Fig-2.a. In both cases the temperature in rural area is lower than suburban and urban area due to the presence of large vegetation fraction (60%). The temperature difference between urban and rural area is ranging from 3°C to

6°C during daytime, which indicates the effect of land-cover conversions and additional anthropogenic heating from traffic and electricity consumption. An average night-time temperature increase of 2°C is owing to anthropogenic and trapped heating from urban canyons. In urban area, higher sensible heat fluxes (up to 700 W·m⁻²) are caused by higher thermal heat capacity of urban surfaces and lower latent heat fluxes (up to 40 W·m⁻²) are attributed to low moisture availability representing the substantial impact of land-cover changes on energy budget. The simulation results are validated at daytime in comparison with observation at Tokai city, while nocturnal temperature differs from 1°C to 3°C due to the lack of urban representations in observed data (Fig-2.b). The newly modified 24-category land-cover data shows the inhomogeneous land-use pattern of Nagoya city in temperature field and surface energy flux distribution. In Figure 3, the distribution of mean temperature illustrates that the center of Nagoya city concentrates high temperature anomalies [3°C-6°C] with surrounding suburban and rural area, and reveals the signature of heat island phenomena. The highest UHI intensity is 6°C happening at 1PM on 3 August 2003. Thus the modified MM5 shows better interpretation of urbanization effect on local meteorology because of urban parameterization and new land-cover classification.

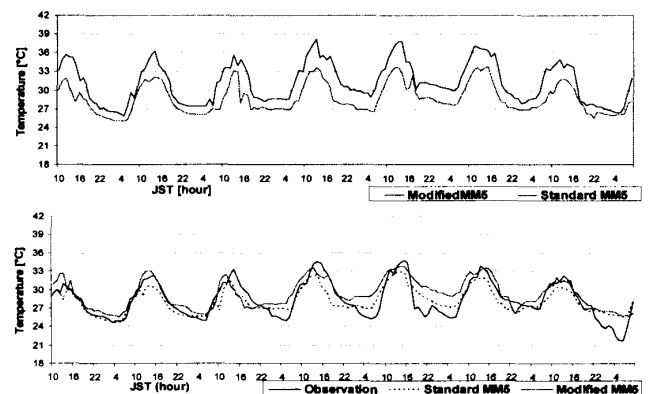


Figure 2. Time series of temperature at 2m, a) in urban area by standard and modified MM5; b) comparison of simulated and observation data.

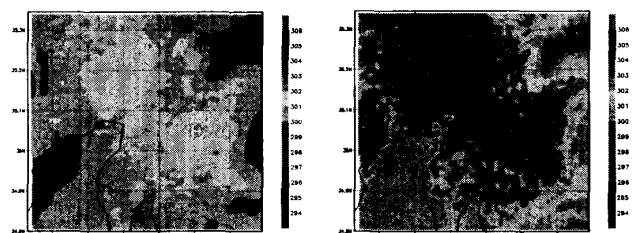


Figure 3. Mean distribution of temperature at 2m in domain D3 by the standard (left) and modified MM5 (right) from 01 to 07 August 2003.