Diagnostic study of effects of large city on heavy rainfall in central Tokyo, based on ensemble simulation

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1. Introduction

In recent years, short-time heavy rainfall has occurred in summer afternoons in Tokyo, causing an inundation under the ground and severe flood above/under the floor. Many numerical studies have demonstrated the effects of cities on short-time heavy rainfall (e.g. Rozoff et al., 2003). However, we were unable to deny the possibility that the results of these numerical studies arose from chaotic effects because precipitation is quite chaotic (Kusaka et al., 2009). One of the valuable methods used to overcome this problem is the ensemble simulation (Kusaka et al. 2009). This study is intended to investigate the effects of urban areas on precipitation during heavy rainfall occurring in central Tokyo, based on ensemble simulation of large members.

2. Methods

We used the Regional Atmospheric Modeling System (RAMS; Pielke et al., 1992) Ver. 4.4 coupled with a single-layer Urban Canopy Model (Zhang et al., 2008). The ensemble simulation in this study consisted of simulations using various objective analysis data as the initial and boundary atmospheric field (RANAL, GANAL, JRA-25, NCEP-FNL and NCE/DOE-R2).

Land use distributions of two types were prepared for numerical simulations; actual land use and virtual land use, in which all urban-type land use was converted to vegetation. Each member was simulated using actual land use and virtual land use.

Simulations were performed on 10 heavy rainfall events in central Tokyo during 1999–2007. An E-S wind system (convergence of easterly wind from the Kashima Sea and southerly wind from the Sagami Bay in Tokyo; Fujibe et al., 2002) appeared at all these events.

Among the ensemble members, E–S wind system appeared only in 24 members. This study is intended to investigate the effects of large city when heavy rainfall occurred under an E–S wind system. Then, we only analyzed these 24 members.

3. Results and Discussion

Results show no large differences in the E-S wind system of the Kanto plain (ca. 100 km × 100 km), even if cities were converted entirely to vegetation. However, the winds that blow to the urban area were strengthened because of the pressure decrease caused by the urban heat island effect. Consequently, the convergence leeward of the urban area was enhanced by the urban heat island. The updraft leeward the urban area was also strengthened by the urban heat island effect.

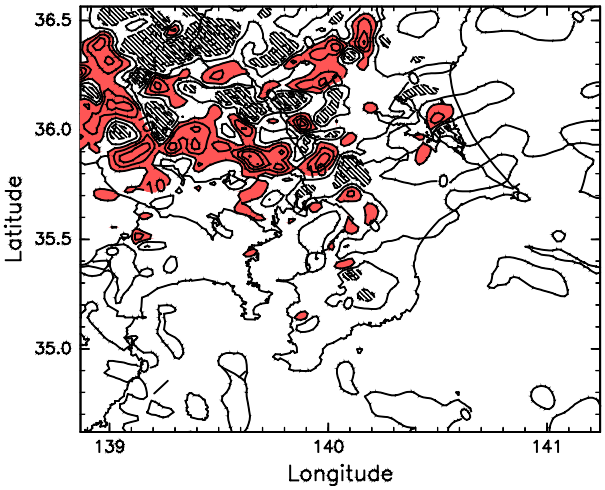

Fig.1. Difference of ensemble mean of 6 hr accumulated precipitation (mm) from 3 hr before rainfall started in the observation. Shaded and hatched areas respectively show greater than 10 mm and below -10 mm.

In addition, the precipitation leeward of the urban area increased despite the decrease of vertical vapor flux from the land surface (Fig.1). The horizontal vapor flux from the southern side of Tokyo increased because of the strengthening of the wind.

We therefore concluded for the case of Tokyo that urban effects alter wind characteristics leeward of the urban area, and develop wind convergence and rainfall there.

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