Numerical simulations of a warm rain event observed in Tokyo, Japan

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1. Introduction

Since 2016, continuous observations of clouds and aerosols have been performed at Tokyo Skytree which is the tallest broadcasting tower in the world, and the upper parts of the tower are often covered by low-level clouds (Misumi et al., 2018; 2022). Cloud droplets and aerosol particles were monitored at the 458 m level of Tokyo Skytree (35.71◦N, 139.81◦E, 460 m above sea level) to elucidate the cloud and precipitation processes in the Tokyo metropolitan area.

In the early morning of 22 July 2019, a warm rain precipitation system brought weak rainfall over Tokyo Skytree. This event is addressed to figure out its cloud and precipitation processes with numerical simulations. As the first step, we are investigating the dependency of simulation results on a choice of parameter values in modeled microphysics. This report gives the preliminary results of the sensitivity test to the parameters in the function giving the number concentration of cloud condensation nuclei.

2. Numerical simulations

A numerical simulation system was established based on the Japan Meteorological Agency's nonhydrostatic model (JMA-NHM, Saito *et al*., 2006). We first performed a simulation at a horizontal resolution of 5 km (5km-NHM) over a 2500 km × 2500 km wide domain as shown in Fig. 1a. Following this, a simulation with a 1 km horizontal resolution was performed (1km-NHM).

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Table 1. The values of parameters that were given in the sensitivity test.

	α_x	ν_x	C	k
Exp I	3	1	300 cm^{-3}	0.63
Exp II	3	1	3000 cm^{-3}	0.63

In the 5km-NHM simulation, the top height of the model domain was 22.1 km. The vertical grid spacing ranged from 40 m at the surface to 723 m at the top of the domain. Sixty vertical layers in a terrain-following coordinate system were employed. The integration time was 45 hours, with a time-step of 15 s. The initial and boundary conditions were obtained from the JMA's mesoscale analysis data (MANAL). The initial time was set to 0300 JST (UTC+9) on 21 July 2019. Boundary conditions were provided every 3 hours.

The vertical grid arrangement in the 1km-NHM was the same as in the 5km-NHM, and the domain size was 500 km × 500 km (Fig. 1a). The integration time used was 30 hours with a timestep of 4 s. The initial and boundary conditions were obtained from the 5km-NHM simulation. The initial time for the 1km-NHM simulation was 6 hours later than that of the 5km-NHM.

In the 5km-NHM, we used the semi-double-moment bulk cloud microphysics scheme in which the mixing ratio and number concentration are predicted for solid hydrometeor classes (i.e., cloud ice, snow, and graupel), but only the mixing ratio is predicted for liquid hydrometeor classes (i.e., cloud water and rain). In the 1km-NHM, we used the option of a double-moment bulk cloud microphysics scheme to predict both the mixing ratio and number concentration of particles for all the hydrometeor

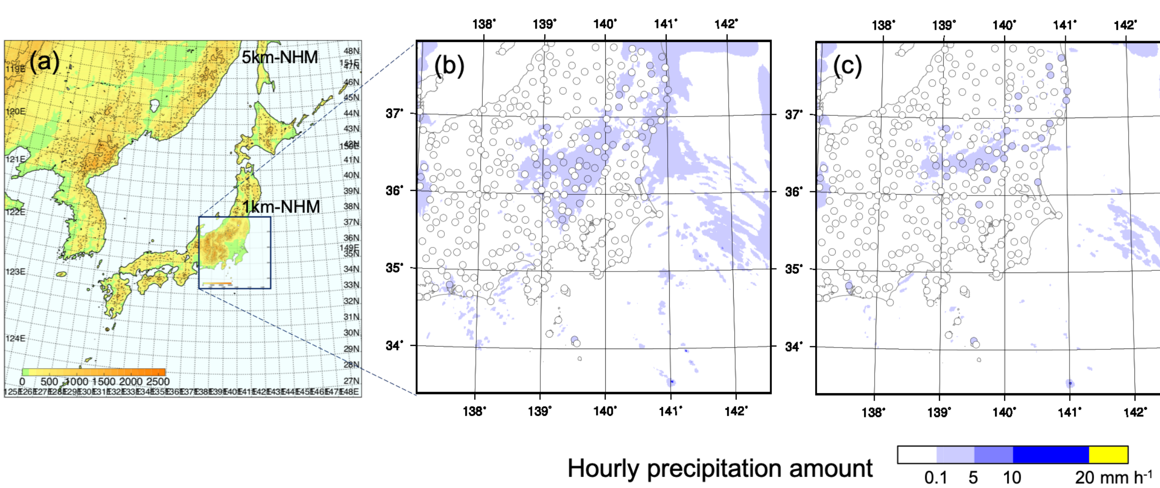

Fig. 1. (a) Computational domains for the numerical simulations: 5km- and 1km-NHM. (b) Hourly precipitation amount at 0300 JST on 22 July 2019 for Exp I. (c) Same as (b) but for Exp II. Circles show the observation stations of AMeDAS.

classes. Equation (1) shows the size spectra of liquid hydrometeors (Cohard and Pinty, 2000).

$$n_x(D_x) = N_x \frac{\alpha_x}{\Gamma(\nu_x)} \lambda_x{}^{\alpha_x \nu_x} D_x{}^{\alpha_x \nu_x - 1} \exp[-(\lambda_x D_x)^{\alpha_x}], \qquad (1)$$

where D_x is the diameter of a particle. Intercept parameter N_x and slope parameter λ_x are diagnosed every timestep using mixing ratio and number concentration of particles. Constant parameters α_x and ν_x are prescribed as 3.0 and 1.0, respectively. The index $x = c$ and r indicate a parameter for cloud water and rain, respectively. The number concentration of cloud condensation nuclei (CCN) is given by the following function,

$$N_{CCN} = C\, S^k, \qquad (2)$$

where S is the supersaturation ratio. C and k are constant parameters. We performed a sensitivity test Exp I and II by setting the (C, k) as (300 cm^{-3}, 0.63) and (3000 cm^{-3}, 0.63), respectively (Table 1).

3. Results

Figures 1b and 1c show the hourly precipitation amount at 0300 JST on 21 July 2019 for Exp I and II, respectively. Circles show observation stations of the Automated Meteorological Data Acquisition System (AMeDAS). Precipitation in Exp I covered a larger area than in Exp II. Compared with the AMeDAS observation, the precipitation area was over- and underpredicted in Exp I and II, respectively, precipitation area. Figure 2 shows the vertically integrated mixing ratio of liquid and solid hydrometeors in the atmosphere (Liquid water dominated the total amount). Exp I (Fig. 1a) predicted less amount of hydrometeors than Exp II (Fig. 1b). Results shown in Figs 1b, 1c, and Fig. 2 indicate that more amount of water precipitated on the ground, thus less amount of water remained in the atmosphere in Exp I.

At Tokyo Skytree, cloud droplet number concentrations (*Nc*) of 50 – 100 cm^{-3} were observed around 0300 JST on 21 July 2019. On the other hand, the predicted *Nc* ranged between 40 – 80 cm^{-3} during the same period in Exp I, while, in Exp II, the predicted *Nc* ranged between 50 – 300 cm^{-3} (not shown). The parameter values given in Exp I (Table 1) showed better results in the addressed precipitation event. Intermediate values between those used in Exp I and II probably are optimal. As it may not always be optimal to adopt the same values, we plan to extend the sensitivity test to other warm rain events observed at Tokyo Skytree.

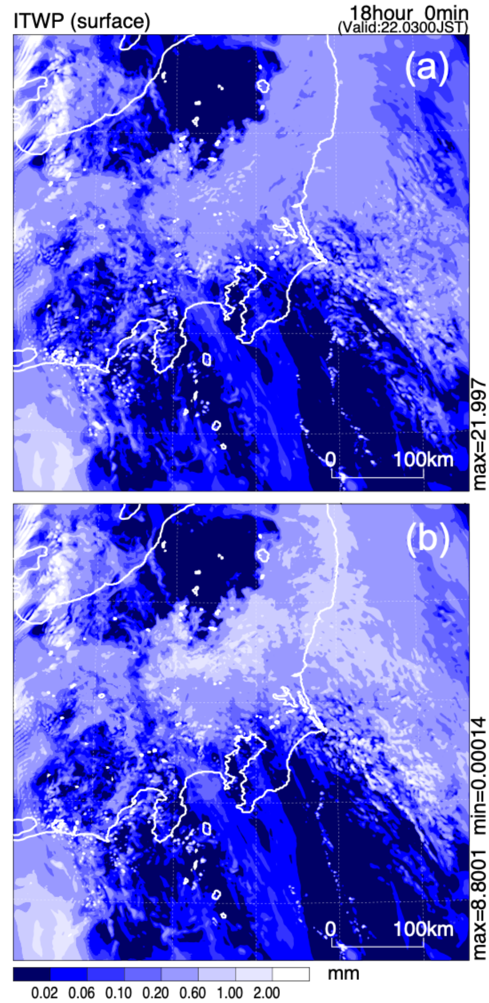

Fig. 2. Simulated distribution of vertically integrated mixing ratio of liquid and solid hydrometeors (mm) at 0300 JST on 22 July 2019 in (a) Exp I and (b) Exp II.

Acknowledgment

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