Precipitation Efficiency in Numerically Simulated Orographic Rainfall Associated with Typhoon Meari (2004)

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1. Introduction

Precipitation efficiency in numerically simulated orographic rainfall has been investigated using a nonhydrostatic model. The targeted area was the east coast of the mountainous Kii peninsula, Japan, same as Murata (2006), refereed to as M2006. The study demonstrated that three characteristic precipitation systems affect the 12-h accumulated rainfall between 0300 Japan Standard Time (JST) and 1500 JST 29 September 2004. The period includes the heaviest rainfall, more than 100 mm/h, at Owase, located at the middle part of the east coast of the peninsula.

In the present study, on the basis of the results of the high-resolution nonhydrostatic simulations, precipitation efficiency is investigated in order to clarify the mechanisms of the heavy rainfall.

2. Numerical model and experimental design

The numerical model we used was the Japan Meteorological Agency Nonhydrostatic Model (JMANHM; Saito et al., 2006) with the horizontal grid spacing of 1 km and 5 km (referred to 1 km-NHM and 5 km-NHM, respectively). We adopt a grid-nesting strategy for the initial and lateral boundary conditions: double nested JMANHM. The nesting procedure is as follows: The initial (2200 JST 28 September 2004) and lateral boundary data for 1 km-NHM (501×501×50 grid points) were obtained from forecasts produced by 5 km-NHM (719×575×50 grid points). The initial (2100 JST 28 September 2004) and lateral boundary data for 5 km-NHM were obtained from the JMA mesoscale analysis data produced with a four-dimensional variational assimilation technique. Kain-Fritsch convection scheme was included in 5 km-NHM in addition to a bulk cloud microphysical scheme.

3. Results

It is desirable to understand the efficiency of a heavy-rainfall event for clarifying the mechanisms of the event. A measure for this purpose is called precipitation efficiency, defined as the ratio of the surface rainfall rate to moisture convergence, or to the sum of condensation and deposition. Market et al. (2003) reviewed previous studies on precipitation efficiency and summarized the precipitation-efficiency values derived from previous studies. Whereas many observational studies have been conducted on precipitation efficiency (e.g., Rauber et al. 1996), few modeling studies have discussed issues related to precipitation efficiency (e.g., Ferrier et al. 1996).

The time series of variables, regarding precipitation, horizontally averaged over a 60-km square centered on Owase are shown in Fig. 1. The variables include water vapor flux convergence, the sum of condensation and deposition, and precipitation, where the former two are vertically integrated variables and the latter is the variable observed at the surface. The period shown in Fig. 1 is divided into three periods: 1) 0300-0600 JST, 2) 0600-0900 JST, and 3) 0900-1200 JST. The first period (0300-0600 JST) corresponds to that when only the precipitation system A of M2006 affects the variables. In the third period (0900-1200 JST), on the other hand, the variables are influenced by all precipitation systems (i.e., A, B, and C of M2006). In contrast, the effects of the systems seem to be less in the second period (0600-0900 JST).

Precipitation efficiency (PE) here is defined to be the amount of rainfall reaching the ground divided by the sum of vertically accumulated condensation and deposition. Other two efficiencies are defined as follows: 1) Condensation efficiency (CE): The sum of vertically accumulated condensation and deposition divided by vertically accumulated water vapor flux convergence, and 2) Multiplied efficiency (ME): The amount of rainfall reaching the ground divided by vertically accumulated water vapor flux convergence. ME therefore is the product of CE and PE.

It is found that PE has the largest value in the period of the heaviest precipitation, leading to the largest values in ME. The calculation of the efficiencies in each period mentioned above shows PE in the third period is larger than that in the first period, although CEs in the two periods are not so different (Fig. 2). The difference in ME between the two periods is attributed to that in PE.

The larger PE suggests that some cloud microphysical processes efficiently produce rainwater. Detailed examination of the production terms for rainwater revealed that accretion of cloud water by rainwater is primarily responsible for the total production of rainwater. It was also found that the accretion term has the largest values in the third period compared with those in the other two periods. The largest values in the accretion term during the heaviest rainfall period are probably attributed to deeper layer of cloud water, compared with those in the other periods. The depth depends on the vertical structure of the precipitation systems. The system C of M2006 is characterized by a structure similar to the primary rainband in a tropical cyclone and consists of deep convective clouds.

Ackowledgements

The author acknowledges T. Kato and S. Hayashi of the MRI / JMA for developing computer codes for nesting.

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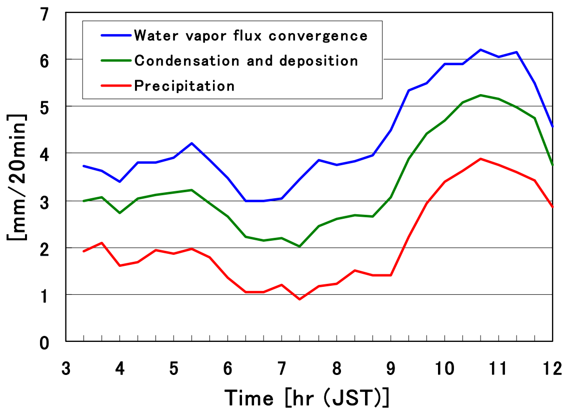

Fig.1 Time series of precipitation, the sum of condensation and deposition, and water vapor flux convergence.

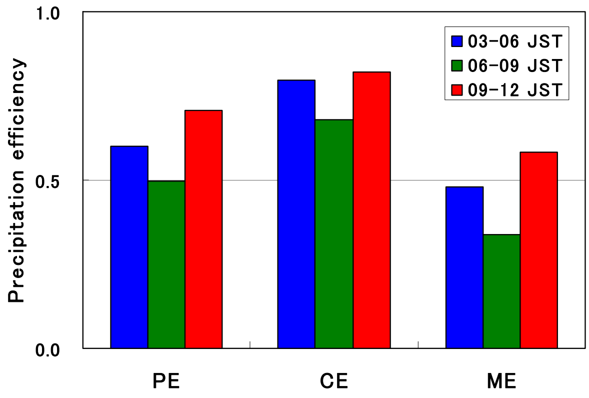

Fig.2 Precipitation efficiency, condensation efficiency, and multiplied efficiency for each periods.