A Cloud-resolving Numerical Simulation for Orographic Rainfall Associated with Typhoon Meari (2004)

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1. Introduction

Heavy rainfall in a mountainous area in Japan caused by typhoon Meari (2004) was investigated using a cloud-resolving model. The targeted area was the east coast of the mountainous Kii peninsula, located at 34N, 136E (see Fig. 1). The typhoon initially tracked northwestward as it gradually intensified and reached its lowest minimum sea-level pressure. The typhoon recurved to the northeast in the East China Sea and made landfall in Kyushu, Japan, at 0830 Japan Standard Time (JST) on 29 September. The storm moved almost parallel to the mountainous spine of Honshu, the mainland of Japan.

Before the typhoon landfall, heavy rainfall in the eastern part of the Kii Peninsula started. From the 12-hour accumulated rainfall amount, ranging between 6 h before and 6 h after the landfall, it is found that the amounts are considerable in the eastern part of the Kii Peninsula (Fig. 1). In particular, the precipitation is more than 400 mm around Owase, located at the middle part of the east coast of the peninsula.

A marked characteristic of this heavy rainfall is that the area of precipitation is far from the storm center: more than 500 km. The goal of this study is to clarify the mechanism of the characteristic rainfall.

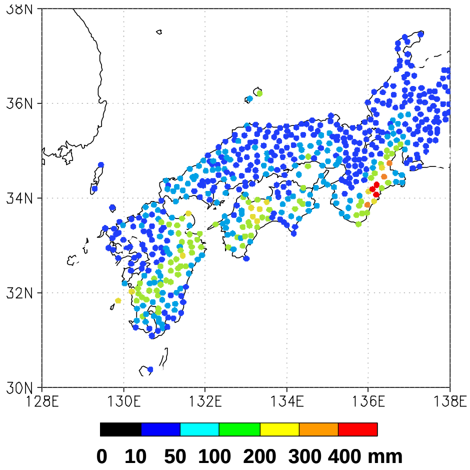

Fig. 1 Horizontal distribution of 12-hour accumulated (from 0300 JST to 1500 JST on 29 September 2004) rainfall amount measured by the JMA rain-gauge network.

2. Numerical model and experimental design

The numerical model we used is the Japan Meteorological Agency Nonhydrostatic Model (JMANHM; Saito et al., 2006) with the horizontal grid spacing of 5 km and 1 km (referred to 5 km-NHM and 1 km-NHM, respectively). We adopt a grid-nesting strategy for the 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) are 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 are obtained from the JMA mesoscale analysis data produced with a four-dimensional variational assimilation technique. Kain-Fritsch convection scheme is included in 5 km-NHM in addition to a bulk cloud microphysical scheme.

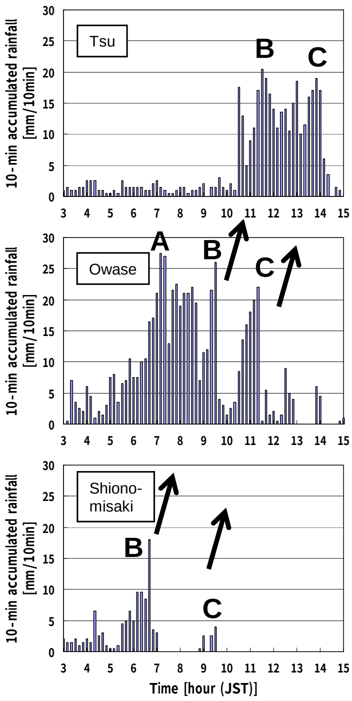

Fig. 2 Time series of 10-minute accumulated rainfall amount observed at three stations located along the east coast of the Kii Peninsula. The location of each observation point is shown in Fig. 3. The peaks corresponding to the precipitation systems A, B, and C are also shown.

3. Partitioning heavy rainfall into three precipitation systems

From radar observations, it was found that the precipitation systems were categorized as follows: A) the stationary system observed around Owase, B) the moving system to the southwest of the system A, and C) the band-like moving system to the southeast of the system B. The categorized precipitation systems were also observed in the time evolution of 10-min accumulated rainfall amount measured with rain gauges located along the coast. In the time series of each observation point, a couple of peaks are found (Fig. 2). The peaks move along the coast from southwest to northeast. The movement seems to be forced by flow in middle troposphere.

The simulation of typhoon Meari using 1 km-NHM is successfully reproduced the heavy rainfall (Fig. 3). The simulated precipitation patterns are favorably compared with the analyzed precipitation, based on radar reflectivity and rainfall amounts measured by rain gauges. The simulation well represents the three precipitation systems mentioned above. Detailed examination of the model fields reveals that the predominant processes for the formation and maintenance of each precipitation system is as follows: system A) Vertical instability in the low-level humid easterly on the slope of mountains located along the east coast of the Kii Peninsula, system B) Horizontal wind shear along the boundary between low-level easterly and south-easterly flow, and system C) Cold pool along the edge of the system and low-level inflow into the system like a tropical cyclone spiral rainband.

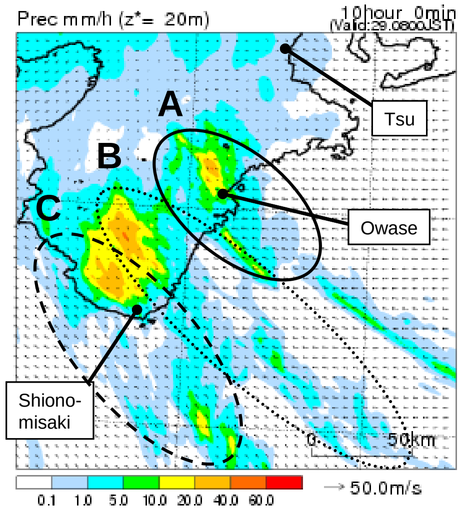

Fig. 3 Horizontal distribution of 1-hour accumulated rainfall amount at 0800 JST on 29 September simulated by JMANHM. The indexes of A, B, and C denote the precipitation systems. The location of each station in Fig. 2 is also shown.

4. Sensitivity of topography and moisture

To investigate the effect of topography on each precipitation system, we conduct a sensitivity experiment in which model topography over the Kii Peninsula is removed. The simulated precipitation is shown in Fig. 4. The most significant difference in the horizontal pattern is that the precipitation system A shown in Fig. 3 disappears in Fig. 4, suggesting that the system A is associated with interaction with the topography. The precipitation systems B and C, on the other hand, are simulated even in the experiment in which the mountain effect is removed. The precipitation patterns of the systems are similar to those produced in the control simulation with topography. The results indicate that the effect of topography on the system B and C is much less than that on the system A.

Sensitivity of the initial field is also investigated using 5-km NHM. Five initial data are used: 2100 JST on 27 September, 0300, 0900, 1500, and 2100 JST on 28 September. The heavy rainfall over the east coast of the Kii Peninsula is well simulated in two experiments, whereas rainfall amount is not so large in other three experiments. Between the two groups of the simulation, there is a crucial difference in moisture. The simulations where the heavy rainfall is well reproduced have relatively large amount of precipitable water compared with that obtained from the other group simulations. The results suggest that moisture play a critical role in the occurrence of the heavy rainfall in both real and model atmosphere.

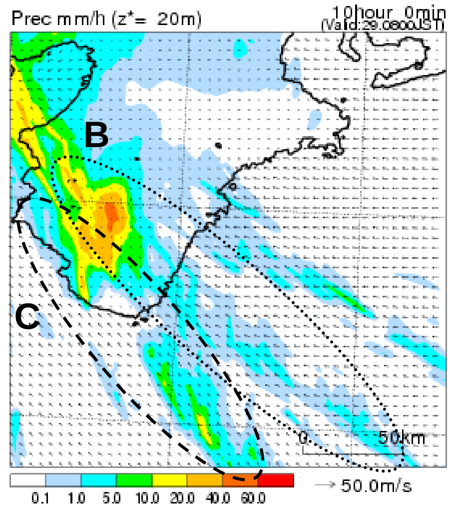

Fig. 4 Same as in Fig.3, but simulated by JMANHM without topography over the Kii Peninsula.

Reference

Saito, K., T. Fujita, Y. Yamada, J. Ishida, Y. Kumagai, K. Aranami, S. Ohmori, R. Nagasawa, S. Kumagai, C. Muroi, T. Kato, H. Eito and Y. Yamazaki, 2006: The operational JMA Nonhydrostatic Mesoscale Model. Mon. Wea. Rev. (in press)