Precipitation Efficiency in Numerically Simulated Heavy Rainfall Associated with Typhoons Man-Yi (2007) and Fitow (2007)

Akihiko MURATA

Meteorological Research Institute / Japan Meteorological Agency, Tsukuba, Ibaraki 305-0052, Japan

1. Introduction

Heavy rain accompanying tropical cyclones risks the life of many people and causes widespread material damage. It is therefore very important to evince the mechanisms of heavy precipitation associated with tropical cyclones. Typical precipitation accompanying tropical cyclones is associated with the eyewall or spiral rainbands.

There exists another type of rainfall associated with tropical cyclones: the area of heavy precipitation is farther from the storm center. For instance, an extremely heavy precipitation event associated with typhoon Meari in 2004 in a mountainous region in Japan characterized that the area of precipitation is 500 km farther from the storm center (Murata 2009; refereed to as M2009). M2009 demonstrated that a mechanism of the heavy precipitation is associated with higher efficiency of precipitation, which is attributed to higher rate of the conversion of could water to rain water via accretion of cloud water by rain, under the condition of intense water vapor flux convergence. It is interesting to compare these findings with those in other heavy precipitation events that occurred far from the tropical cyclone center. The comparison enables us test whether the mechanism holds in those different cases.

2. Numerical model and experimental design

The numerical model used is the Japan Meteorological Agency Nonhydrostatic Model (JMANHM; Saito et al. 2006). The horizontal grid has 701x701 grid points and the grid spacing is 1 km. The vertical coordinate is terrain-following and contains 50 levels, with variable grid intervals of 40 m to 904 m. The lowest level is located at 20 m from ground surface, whereas the highest level is at 22 km. The time-step intervals are 5 s. The initial and boundary data are provided by the JMA mesoscale analysis data.

3. Cases

3-1 Typhoon Man-Yi (2007)

Heavy rainfall in the southeastern part of Kyushu, a southwestern part of Japan, started more than 24 h before the typhoon landfall. Observed 1-h accumulated rainfall amounts at Hyuga, located in a southeastern part of Kyushu (32.4N, 131.6E), demonstrated that the present heavy precipitation event is extreme on a short time scale (not shown). For example, data showed 84 mm per 1 hour between 0950 and 1050 JST 13 July.

3-2 Typhoon Fitow (2007)

Heavy rainfall in the northeastern part of Honshu, the mainland of Japan, started more than 24 h before the typhoon landfall. Observed 1-h accumulated rainfall amounts at Hippo, located in a northeastern part of Honshu (37.8N, 140.7E), demonstrated that the present heavy precipitation event is extreme on a short time scale (not shown). For example, data showed 83 mm per 1 hour between 2040 and 2140 JST 5 September.

4. Results

Because extremely heavy precipitation was observed around Hyuga (Hippo) associated with typhoon Man-Yi (Fitow), a 60-km square area centered on Hyuga (Hippo) is set for calculating precipitation efficiency. The time series of variables, regarding precipitation efficiency, horizontally averaged over the area 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.

Three kinds of precipitation efficiency used are defined as follows: 1) Condensation efficiency (CE): The sum of vertically accumulated condensation and deposition divided by vertically accumulated water vapor flux convergence, 2) Rainfall efficiency (RE): The amount of rainfall reaching the ground divided by the sum of vertically accumulated condensation and deposition, and 3) 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 RE. Two periods are considered for calculating the precipitation efficiencies as follows: 0400-0600 JST and 0600-0800 JST for the Man-Yi case and 1600-2100 JST and 2100-0200 JST for the Fitow case. The latter (former) period in each case corresponds to that when relatively heavy (light) precipitation occurred.

The calculated precipitation efficiencies show that ME in the latter period has higher value than that in the former period in both cases (Fig. 2). The period of the higher ME corresponds to that of heavier rains. The difference in ME between the two periods is attributed to those in both CE and RE. The results suggest that condensation and deposition occur efficiently in addition to efficient production of rainwater by cloud microphysical processes, whereas only the latter effect was dominant in M2009. The structure of precipitation systems may be responsible for the relative importance of CE or RE. More detailed work is necessary to resolve this issue.

References

Murata, A., 2009: A mechanism for heavy precipitation over the Kii Peninsula accompanying typhoon Meari (2004). J. Meteor. Soc. Japan, 87, 101-117.

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., 134, 1266-1298.

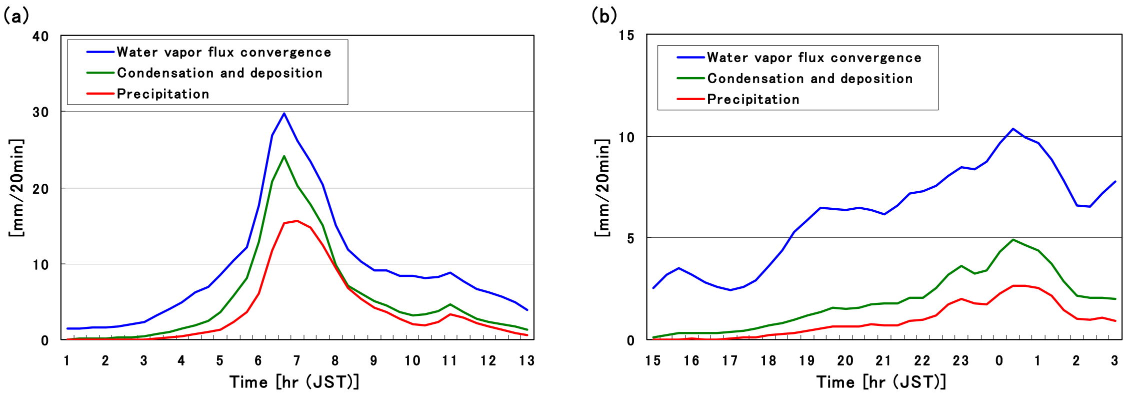

Fig.1 Time series of precipitation, the sum of condensation and deposition, and water vapor flux convergence for the cases of (a) typhoon Man-Yi (from 0100 to 1300 JST 13 July 2007) and (b) typhoon Fitow (from 1500 JST 5 September to 0300 JST 6 September 2007).

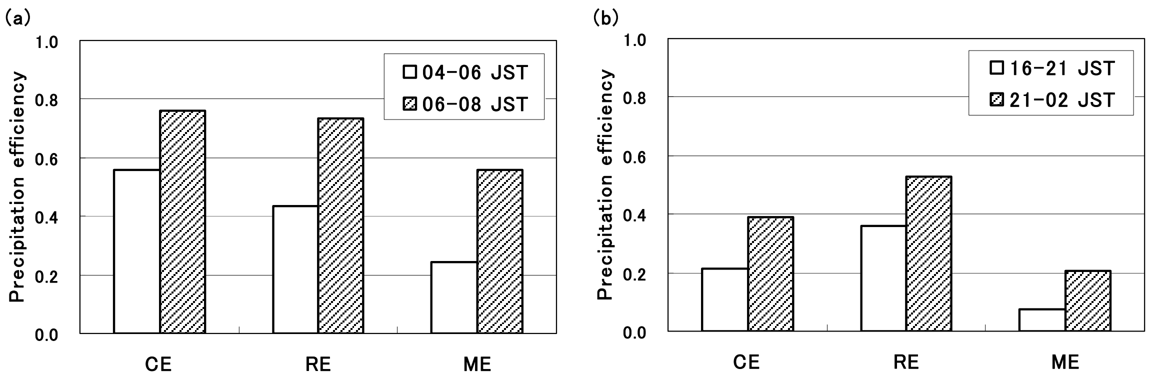

Fig.2 Condensation efficiency (CE), rainfall efficiency (RE), and multiplied efficiency (ME) for the cases of (a) typhoon Man-Yi and (b) typhoon Fitow.