II − 3 Influence of Spatial Rainfall on Flood Hydrograph by Distributed Model

Dept. of Civil Engineering, The University of Tokushima. Members. ○ Huaxia Yao and Michio HASHINO

INTRODUCTION

Hydrological events of flood, their magnitude and timing, are usually determined by rainfall distribution in a basin and the basin's topography-soil-landuse conditions. However no conclusive results have been obtained as for the relation of spatial rain property and runoff generation. Some authors (e.g. Dawdy and Bergman, 1969; Wilson *et al.*, 1979; Corradini and Singh, 1985) have suggested that natural catchments show a strong sensitivity to rainfall pattern, especially for very large basins (several 10,000 km^2). As for small catchments, urban catchments may be the most sensitive to the spatial variability of rainfall (e.g. Niemczynowicz, 1987). In a medium-sized basin (some 100 to a few 1000 km^2), however, there is no such evidence or strong sensitivity (e.g. Obled *et al.*, 1994).

Most of researches mentioned above applied distributed models. A recent study (Yao *et al.*, 1998) suggested that the distributed model behaves better than the lumped model when rainfall is not heavy and is very non-uniform in space. Therefore a distributed model is necessary for testing the role of rainfall pattern.

In this study, effects of rainfall distribution on flood generation in the Fuji River basin of 3,432 km^2 are estimated by a distributed model. Rainfall scenarios are supposed, as available data can not provide enough comparable rainfall inputs. Then responses of flood to supposed scenarios are analyzed.

Fig. 1 Basin schematization

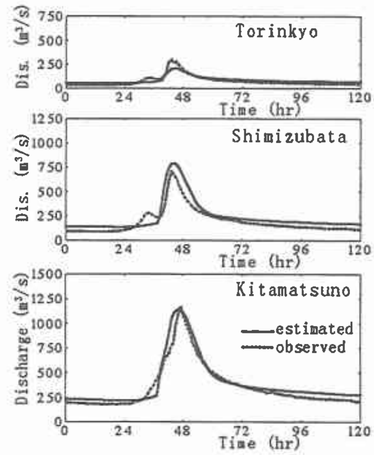

Fig. 2 Hydrograph for three sites

MODEL AND VALIDATION

The Fuji River basin is located at the central-southern Japan, with a small lowland in the center and many mountains around it. The basin is schematized into 3376 grid elements of 1 km resolution. Fig. 1 shows the schematization and drainage network drawn from digital elevation model(DEM). In the distributed model (Yao *et al.*, 1998), interception, evapotranspiration, soil water adjusting, and various outflows are calculated for each grid, and these outflows are routed through the drainage network onto the outlet named Kitamatsuno. Meteorological inputs such as temperature and humidity are spatially allocated to each grid by a spatial regression method, and model parameters are also spatially calibrated with discharge and the geographical information system(GIS) data. Estimated and observed hourly runoff processes are illustrated in Fig. 2 for three discharge gauges of Torinkyo, Shimizubata and Kitamatsuno, at the upper, middle and lower stream respectively, giving good reproduction of hydrograph along the river.

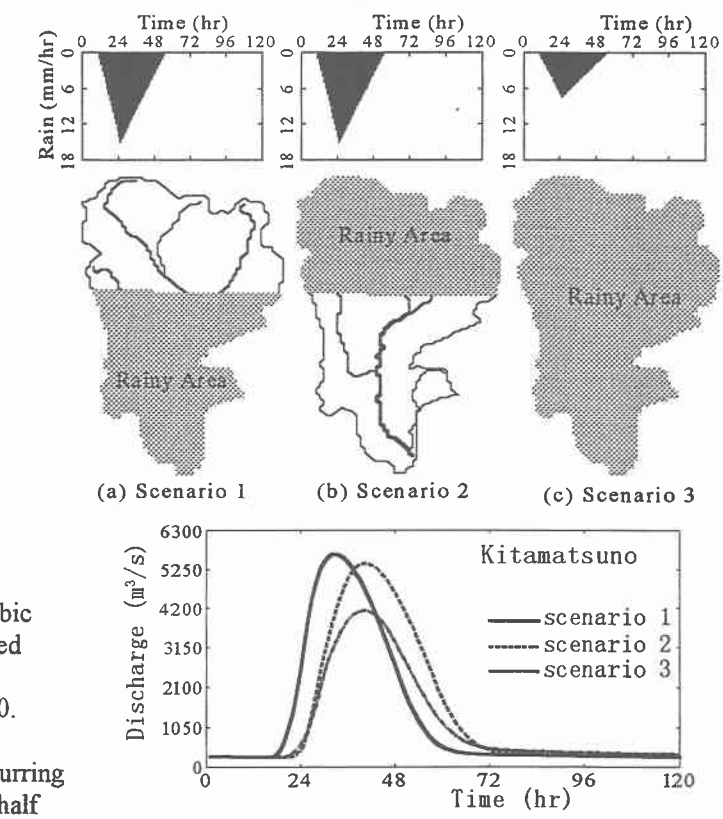

Fig. 3 Scenarios (S1, S2 and S3) and responses

SCENARIOS AND RESPONSES

Five scenarios of rainfall pattern are considered. All of them have a same total volume (0.55 billion cubic meters). Scenario 1 (S1) is a rainfall event concentrated on the lower half part of basin as shown in Fig. 3, temporally beginning at hour 11 and ending at hour 50. Scenario 2 (S2) is a rainfall event concentrated on the upper half part. Scenario 3 (S3) is a rainfall event occurring uniformly on the whole basin, but its intensity is just half of that of S1 to give a same rainfall volume. Corresponding floods at the outlet, estimated by the distributed model, are also plotted in Fig. 3. S1 produces a larger and quicker peak flow than S2, because the rainfall fallen in the lower part experiences less diffusive attenuation redistribution in the basin. S3 produces flatter and slower peak flow than S1 and S2, as the uniform rain has a smaller intensity. Note that the peak flow is not so different between two extremely different scenarios of S1 and S2.

Scenario 4 is a moving rainfall event (Fig. 4). The beginning rain falls on the lower part at hour 11, and then gradually moves upward at a speed of about 1 km/h. At hour 21 and hour 31 the rain is in the central region, and at hour 50 it arrives at the upper part. On the contrast scenario 5 is a rainfall moving downward at same speed as the upward. They have same total volume over the basin. From the flood hydrographs as shown in Fig. 4 it is seen that S4 produces a much smaller but quicker peak flow than the S5 does. The upward moving has the rain experience more attenuation in soils and rivers, and therefore makes the peak flattened. But the fact that the rainy area of upward moving rain is relatively closer to the outlet than the rainy area of downward moving rain determines the quicker occurrence of peak flow.

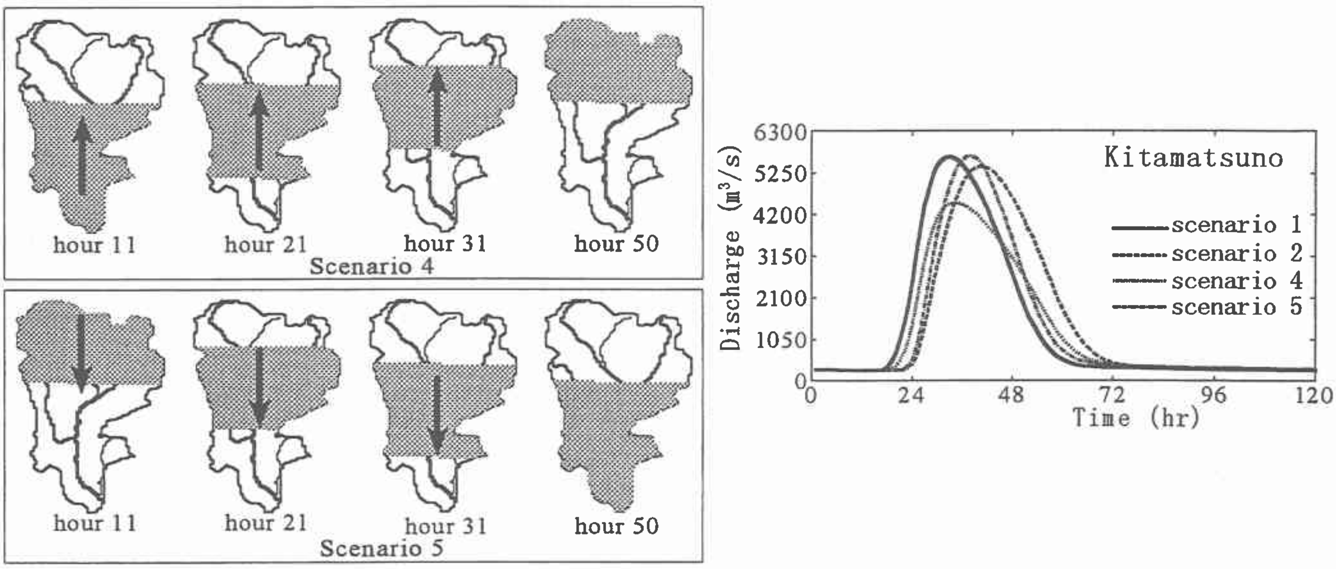

Fig. 4 Two scenarios of moving rainfall and their flood processes

Furthermore comparing the flood of S4 with the flood of S1 without moving, S4 makes its peak flow flatter and a little slower. And downward moving S5 makes the peak flow bigger and quicker than S2 without moving.

It is concluded that the influence of spatial rainfall on flood formation can be well simulated by a distributed model. A rain event concentrated in the lower part of basin forms a larger and quicker peak flow than does a rain event concentrated in the upper part. A rain moving upward in the basin forms a smaller but quicker flood than a rain moving downward. And the upward moving makes flood flatter and slower, the downward moving makes flood bigger and quicker, compared with the rain without moving.

References

Corradini, C. and Singh, V. P. (1985) Effects of spatial variability of effective rainfall on direct runoff by geomorphologic approach. *J. Hydrol.* **81**, 27-43.

Dawdy, D. R. and Bergman, J. M. (1969) Effect of rainfall variability on streamflow simulation. *Water Resour. Res.* **5**, 958-969.

Niemczynowicz, J. (1987) Storm tracking using raingauge data. *J. Hydrol.* **93**, 135-152.

Obled, Ch., Wendling, J. and Beven, K. (1994) The sensitivity of hydrological models to spatial rainfall patterns: an evaluation using observed data. *J. Hydrol.* **159**, 305-333.

Wilson, C. B., Valdes, J. B. and Rodriguez-Iturbe, I. (1979) On the influence of the spatial distribution of rainfall on storm runoff. *Water Resour. Res.* **15**, 321-328.

Yao, H., Hashino, M., Terakawa, A. and Suzuki, T. (1998) Comparison of distributed and lumped hydrological models. *Annual J. Hydraulic Eng., JSCE* **42**, 163-168.