Utilization of Radar-Raingauge for Flood Management

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ABSTRACT: In order to use radar rainfall data for flood management, it is necessary to study and develop a method for optimum error correction to obtain radar rainfall values that agree closely with surface rainfall data. This paper proposes an optimum estimation method for calculating rainfall in a river basin by using data from surface raingauges and radar raingauge systems. This paper also reports on recent applications of radar raingauge systems for accurate simulation of flood discharge based on river basin rainfall values obtained from radar raingauge systems.

1 INTRODUCTION

Surface rainfall is an amount of rain observed at a point on the ground surface and, hence, is also known as point rainfall. Radar rainfall is a rainfall intensity measured from radar beam echoes returned from rain drops in the air. In Japan, radar rainfall is expressed as the average of rainfall values obtained from a zone defined by a horizontal distance of 1.5 km and an angle of 1.4 degrees.

If radar rainfall data are to be used for flood management, necessary information is areal rainfall in the river basin of interest. In the conventional methods using point rainfall data obtained from surface raingauges, areal rainfall is estimated from point rainfall by using methods such as the representation coefficient method, the Thiessen polygon method and the isohyetal method.

The radar rainfall approach is very advantageous because one-kilometer-mesh rainfall intensity data can be obtained. In the surface rainfall method, the density of raingauges in Japan is only one in 50 to 100 km2, so areal rainfall estimation errors are inherently large.

Although radar raingauge systems are advantageous as mentioned above, radar rainfall data cannot be used on a quantitative basis if they do not agree closely with surface rainfall data.

Quantitative application of radar rainfall data, therefore, requires error correction using rainfall data obtained from surface-based observation.

Estimation errors can be corrected by using as many reliable surface raingauges as possible and checking radar rainfall values against surface rainfall values while trying to reflect areal distribution patterns captured by radar raingauge systems. In this sense, surface raingauges play a critical role in error correction.

In order to make effective use of radar rainfall data for flood management, it is necessary to study and develop a method for optimum error correction that can be used to calculate radar rainfall values consistent with surface rainfall values.

This paper proposes a method for optimum estimation of rainfall in the river basin of interest by use of surface raingauges and radar raingauge systems, and reports on recent applications of radar raingauge systems for accurate simulation of flood discharge based on river basin rainfall values obtained from radar raingauge systems.

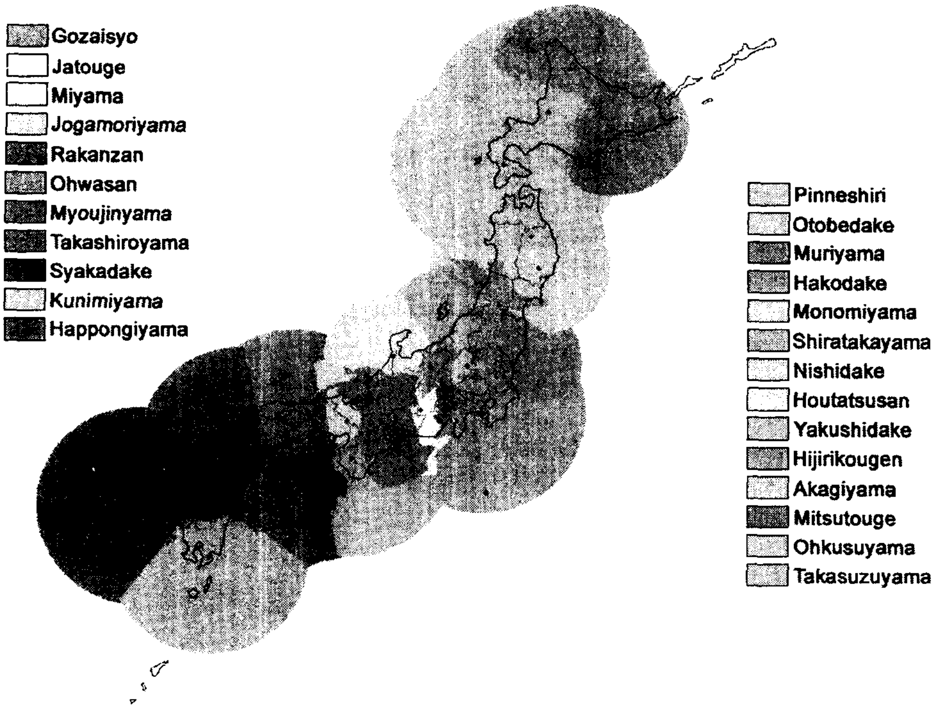

Fig. 1. Situation and observed area of Radar Raingauge in Japan

2 Procedure for Radar Rainfall Error Correction

To ensure consistency of radar rainfall values with surface rainfall values, error correction processing described in the following table is performed.

Table 1. Radar rainfall error correction methods

Category		Description
Homogenization of radar data	Obstruction error correction	Error correction to offset reductions in received power (after reflected by rain) due to obstacles such as mountains
	Distance error correction	Error correction based on the relationship between the distance from the radar site and the radar rainfall/surface rainfall ratio
	Matching	Radar rainfall values are matched to the average hourly rainfall values based on surface rainfall data according to the ratio between the average hourly rainfall obtained from the surface raingauge stations in the radar observation area and the average hourly rainfall for the radar meshes directly above those surface raingauge stations.
Radar synthesis		Estimation of rainfall in overlapping zones of adjoining radar observation areas; synthesis based on a one-kilometer-mesh synthesis table
Calibration by dynamic window (DW) method		The correction factor for a given radar mesh is estimated by averaging by the moving average method the correction factors for the telemeter locations near the mesh of interest. Many methods use weighting based on the distance between the mesh of interest and a telemeter. A characteristic of the DW method is that it does not use weighting based on distance; instead, it uses weighting based on the degree of reliability of the correction factor fi at the telemeter location.

3 Locations of Surface Raingauges and Accuracy of Radar Raingauge System

3.1 Density of Surface Raingauges

Observation data from surface raingauges are used for correction of radar rainfall values. To evaluate the influence of the spacing of surface raingauges on areal rainfall estimation, we compared the tendencies of basin average rainfall values obtained from different mesh scale arrangements.

Average areal rainfalls were calculated on radar rainfall mesh domains (1 km mesh, 50 km × 100 km) covering the study area, and the values obtained from different mesh scale arrangements were compared.

All 1 km meshes (STEP 1; the number of effective meshes: 5,000)
Every two (2 km) meshes (STEP 2; the number of effective meshes: 1,250)
Every three (3 km) meshes (STEP 3; the number of effective meshes: 578)
Every five (5 km) meshes (STEP 5; the number of effective meshes: 200)
Every seven (7 km) meshes (STEP 7; the number of effective meshes: 120)
Every 10 (10 km) meshes (STEP 10; the number of effective meshes: 50)
Every 15 (15 km) meshes (STEP 15; the number of effective meshes: 28)
Every 20 (20 km) meshes (STEP 20; the number of effective meshes: 16)

Absolute errors from the average rainfall calculated using the one-kilometer mesh rainfall values (hereafter referred to as the "STEP 1 rainfall") were compared graphically. Absolute errors on a total-rainfall basis from the average hourly rainfall and STEP 1 rainfall are tabulated below.

(Absolute error) = Σ(|(Hourly rainfall for STEP n) − (Hourly rainfall for STEP 1)|)

As shown, the errors for hourly rainfall do not show significant differences, but there are considerable differences between the absolute errors for STEP 7 (one rainfall data set per approx. 50 km2) and STEP 10 (one rainfall data set per approx. 100 km2).

From these results, it can be concluded that for the rainfall event considered, one surface raingauge per about 50 km2 is appropriate.

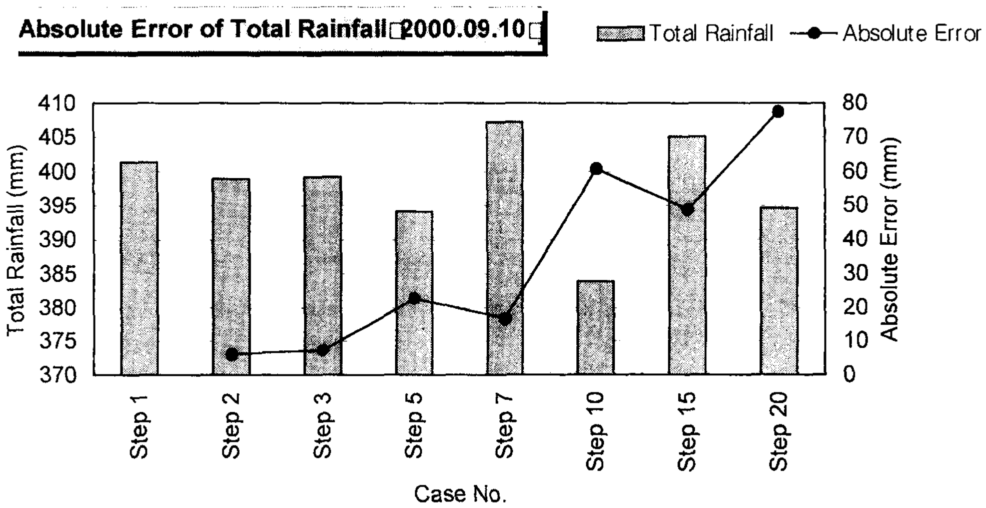

Fig. 2. Absolute error comparison by the total rainfall

3.2 Accuracy of Average Areal Rainfall Calculation

Areal rainfall values calculated from observation data from surface raingauges were compared with areal rainfall values obtained from radar raingauge systems. The September-1998 rainfall in a river basin (hereafter called the "M River Basin") was used a study case. In the study, the effects of missing data from a raingauge station within or adjacent to the M River Basin on the basin average rainfall were compared using the surface rainfall data, the Thiessen method and radar rainfall data.

The results thus obtained indicate that the importance of the validity and stability of radar rainfall data increases in cases where part of surface rainfall data is missing, and that the rainfall at the observation point at which a rainfall measurement could not be obtained can interpolated to a certain degree.

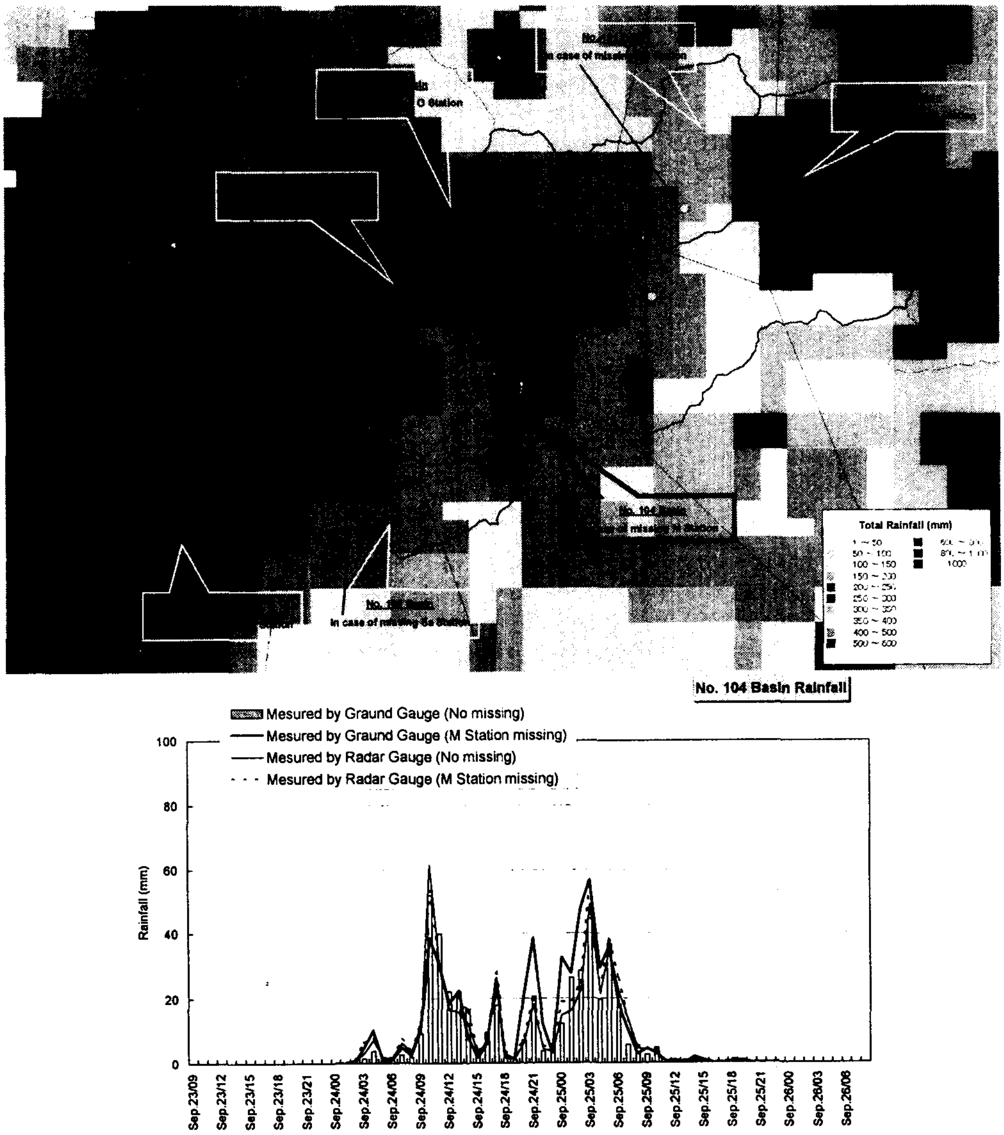

Fig. 3. Comparison of the ground rainfall in No.104 valley at the time of M observatory missing, and radar rainfall

4 Comparison in Terms of Runoff

Figure 3 compares the results of runoff calculations performed using, as inputs, basin average rainfall values calculated from surface rainfall data and those calculated from radar rainfall data.

As shown, the results indicate that both surface rainfall data and radar rainfall data are fairly accurate partly because the surface raingauges are located appropriately.

Table 2. Surface raingauges located upstream of downstream reference points

	Drainage area (km^2)	No. of raingauge stations in river basin	Coverage of single station (km^2)
D River	126.90	9	14.1
Y River	2811.00	43	65.4
H River	1210.00	25	48.4
M River	468.30	13	36.0
K River	68.60	2	34.3
S River	42.97	0	–
F River	42.28	1	42.3

As in the case of S River shown in Table 2, however, a river basin where surface rainfall data are not available shows a runoff pattern as shown in Figure 3, indicating that areal rainfall distribution is captured with very high accuracy.

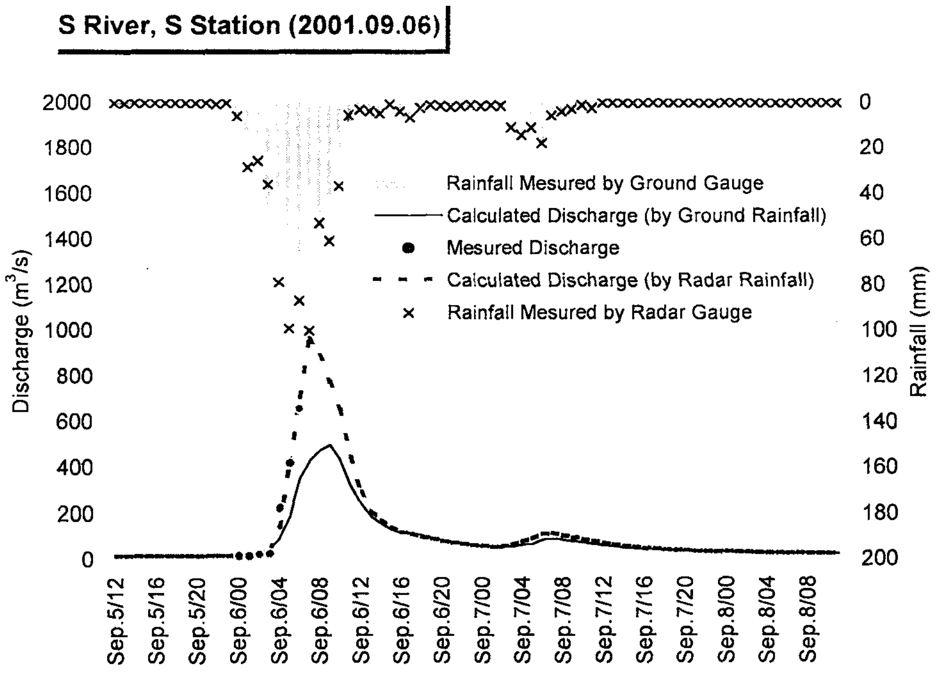

Fig. 3. The example of outflow calculation result comparison (S river and September, 2000 rain)

5 Surface Rainfall Values Used for Radar Rainfall Correction

In cases where radar rainfall values are to be corrected by using surface rainfall data, it is important, before conducting an analysis, to know in advance the method of installing surface raingauges to be used for error correction, the observation method, accuracy of observation (accuracy of measuring devices, influence of storms, influence of ground surface features) and the method of calculating basin average rainfall.

The following sections describe the methods for determining the optimum arrangement of surface raingauges.

5.1 Telemeter locations optimized for all types of rainfall

It is generally said that one raingauge is needed for every 50 km2. The results of this study also indicate that areal rainfall distribution cannot be measured accurately if there is not at least one rainfall observation station for every 50 to 100 km2 or so.

The key to accurate determination of the areal distribution of rainfall is the ability to detect changes in rainfall distribution due to not only telemeter density but also other factors such as topography. It is desirable, therefore, to identify patterns of rainfall distribution and place raingauge stations at all locations where distribution changes occur (e.g., areas prone to intense rainfall) and raingauges can be installed.

5.2 Limit of areal rainfall determination by the Thiessen method

Areal rainfall distribution can be determined accurately by properly locating telemeters. The results of this study also indicate that in river basins where telemeters are more or less properly located, there are no major differences between the areal rainfall distribution based radar data and the areal rainfall distribution based on surface raingauge data.

Accuracy of areal rainfall determination, however, may be significantly affected in cases where a rainfall event of the type that cannot be captured accurately with existing telemetry networks or in cases where one or more telemeter stations have failed to collect data.

5.3 Telemeter locations designed for radar rainfall error correction

By using observation data from radar raingauge systems in combination with telemetry data, accuracy of the determination of areal rainfall distribution can be improved if the density of telemeter raingauges is adjusted appropriately.

If higher accuracy of areal rainfall determination is to be achieved, however, it is desirable that telemeter information concerning the points of distribution changes (e.g., areas prone to intense rainfall), which can be obtained from rainfall distribution patterns based on data on many rainfall events, be available. The relationship between telemeter locations and the accuracy of corrected radar rainfall data needs to be analyzed for each rainfall area.

6 Areas of Application of Radar Rainfall Data

River basin rainfall data used in various areas of conventional river management such as flood prediction are basin average rainfall data obtained by the Thiessen method from surface rainfall observation. Use of radar rainfall data in the field of river management has the following advantages:

(1) Areal rainfall distribution can be determined in detail.

Radar rainfall data are particularly useful when used for areas in which the density of surface raingauges is not very high, areas prone to localized heavy rains because of topographic characteristics and areas in which rainfall is very unevenly distributed.

(2) Constants for lumped runoff models can be analyzed accurately.

Since the amount of rainfall, which is an input for a runoff model, can be determined accurately, model parameters can be analyzed correctly. In the case of a storage function model, for example, it becomes possible to analyze not only the values of constants K and P but also other values such as the initial runoff coefficient f1 and the saturation rainfall Rsa from the relationship between runoff volume and areal rainfall. As a result, accuracy of runoff modeling will be improved.

Use of radar rainfall data corrected by homogenization and dynamic-window (DW) calibration should make it possible to obtain discharge values close to actual discharges. From the standpoint of management, possible applications of rainfall data thus obtained may include the following:

- □ Prediction of reservoir inflow in dam management
- □ Use for erosion and sediment control in torrent management (At present, areas that require erosion and sediment control planning do not have an adequate network of surface raingauges.)
- □ Flood prediction and facility management (e.g., dam operation, pump operation) in small river basins where rain runs off quickly
- □ Use for road management

If the proposed method is validated through the application of distributed models to major rivers, it will become possible to draw up detailed facility and other plans. By constructing a flood prediction model based on a distributed model that uses one-kilometer-mesh radar rainfall data, accurately predicted discharge values at given locations other than discharge observation points can be output in real time. This will make it possible to provide various information that is useful in many ways for flood defense, such as detailed and early flood advisories and warnings. It will also be possible to develop a system that is useful for disaster prevention planning by linking radar rainfall information (maximum rainfall, cumulative rainfall) to other data, such as land use data, soil property data, past disaster data, debris flow risk data, flood defense information, evacuation information, and population and property data, for use on geographic information systems.

7 CONCLUSION

Too much rain causes floods, while too little rain results in water shortage (drought). As an input to river runoff processes, therefore, rainfall is essential for flood and drought prediction.

In this study, differences between runoff analysis results obtained from basin average rainfall values derived by the Thiessen method and from radar rainfall values have been evaluated. The findings of this study are as follows:

- □ In some of the river basins studied, differences between surface rainfall data and radar rainfall data are not significantly large because surface raingauges in those river basins are relatively well-located. Radar rainfall information, however, is still useful in determining the areal distribution of rainfall.
- □ The effects of different densities of radar rainfall and surface rainfall information were studied. As a result, it was concluded that the desirable density of surface raingauges about one raingauge per 50 to 100 km2.
- □ Radar rainfall data become all the more useful and reliable in cases where surface raingauges have failed to collect data. With radar rainfall data, it is possible to some degree to estimate the rainfall at an observation point from which rainfall data could not be collected.
- □ In areas where the density of surface rainfall raingauges is low, radar rainfall data enable very accurate determination of areal rainfall distribution.

8 REFERENCE

Yoshino, Fumio (2002). Radar Hydrology. Morikita Shuppan, Japan.

Fukami, Chikao (2002). "How should we utilize the radar-raingauge." J. River, Japan River Association, Vol. 58, No 1, pp. 99-102.