第Ⅱ部門

Probabilistic Flood Forecasting Using Weather Radar and Distributed Hydrologic Model - Case Study of Typhoon Rusa, 2002 -

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1. Introduction

Accurate flood forecasting on a real-time basis has long been the principal aim of many hydrologists, and a large number of rainfall–runoff models have been developed and applied toward the forecasting problem.

In operational hydrology, real-time forecasting requires not only well developed rainfall–runoff models, but also a method for continuous adjustment of the forecast based on the error observed from earlier forecasts. This continuous correction, with real-time measurement and updating, is one of the most valuable schemes for improving the forecasting performance of any rainfall–runoff model.

Recent trend of flood forecast is away from the conventional simple deterministic forecasts of hydrographs toward offering probabilistic forecasts, which include its prediction uncertainty. Deterministic flood forecast specifies a point estimate of the predicted values, such as precipitations and river stages/discharges. On the other hand, probabilistic forecast specifies a certain probability distribution function of the predicted values. The predictive probability in a probabilistic forecast is a numerical measure of the certitude degree about the intensity of a flood event, based on all meteorological or hydrological information utilized in the forecasting process.

This study presents a real-time flood forecast algorithm in a probabilistic way with a radar image extrapolation model and a distributed hydrologic model.

2. Short-term Rainfall Forecast using Radar Image Extrapolation Model

New attempt of ensemble rainfall-runoff prediction is presented with radar rainfall prediction and Spatial Random Error Field (SREF) simulation. First, the translation model (Shiiba et. al., 1984), a radar image extrapolation model, gave deterministic rainfall predictions. Using the past several hours' prediction results, its prediction error structure was analyzed by comparing with observed rainfall fields. The analyzed error structure was composed of basic statistics, spatial distribution pattern, and spatial correlation coefficient of the error, etc. To update the analyzed error structure on a real-time basis, statistic field, which is mean and standard deviation fields of the error, was prepared as shown in Figure 1. The statistic field contains the current characteristics of the prediction error. Then SREF was generated to give random values on the error field simulation. SREF is a field of spatially correlated random values with zero mean and unit standard deviation; $N(0,1)$. The spatial correlation of the SREF is determined by the current error fields. Finally, the statistic field converted SREF to the target error field, which is the aim of the error filed simulation.

The simulated error fields, which successfully keep the analyzed error structure, not only give a probable rainfall field variation for the ensemble simulation but also improve accuracy of the deterministic prediction by correcting the possible prediction error (Kim et. al., 2006). Then, the generated probable error fields with the deterministic field were given to a distributed hydrologic model to achieve a probabilistic runoff prediction.

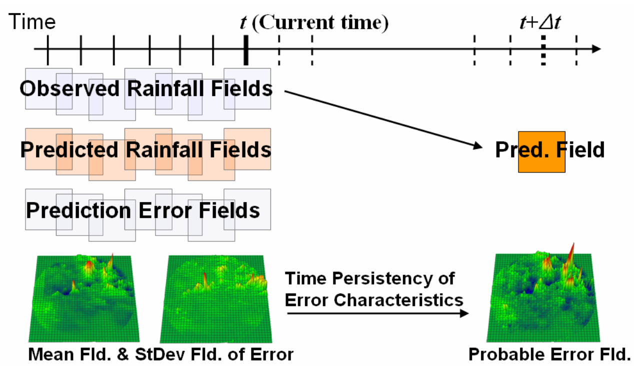

Fig.1 Schematic drawing of the probabilistic error field simulation with the error persistency assumption

3. Distributed Hydrologic Model with Real-time Update Algorithm

The objective of the real-time update algorithm was to utilize online hydrologic information in a physically based distributed model, CDRMV3 (Kojima et. al., 2003) using the Kalman filter.

For the incorporation of the filtering concept into a distributed model, there are several barriers to be overcome. First, linearized equations for the system dynamics are necessary in the filter for projecting the state variables and their error covariance. However, the Monte Carlo simulation method permit the derivation of forecast error statistics in the Kalman filter algorithm, and thus, the inefficiency involved in the linearization of system states can be eliminated.

Second, as an alternative to a linear observation function in the measurement update algorithm of the filter, this study introduced an external relationship of observed data and the internal state variables of the hydrologic model. Here, the observed data are outlet discharge and the state variable in the Kalman filter algorithm is the total amount in storage in the basin. Rather than inputting a linear function of the observation and the system states into the Kalman filter, a table of those two sets of values successfully defines the nonlinear interaction in the updating algorithm.

The last problem to be considered was how a very large number of state variables, which are usually based on the fine grid cells of a distributed hydrologic model, can be updated at the same time without excessive computational burden. A simple but very efficient method using a ratio of the state variables makes it possible to solve this restriction on the application of Kalman filter with a distributed hydrologic model (see Figure 2). The Kalman filter algorithm updates the total amount in storage in the basin, and a ratio of the updated and simulated storage amount is calculated and applied to each of the internal state variables on a fine grid cell.

The distributed hydrologic model coupled with the Kalman filter algorithm offers improved simulation results with encouraging forecast accuracy (Kim et. al., 2005).

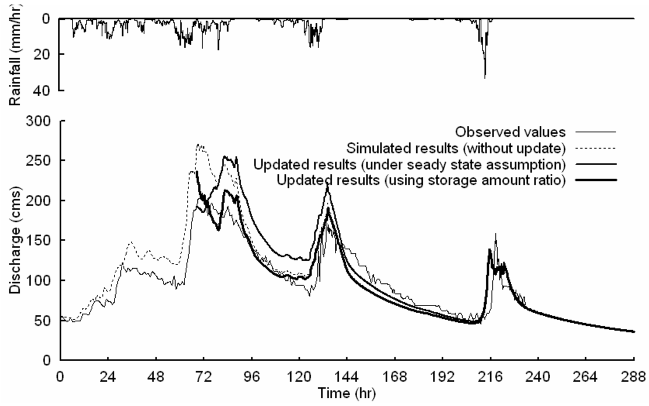

Figure 2. Comparison of simulation results without update and with each update assumption; the steady-state assumption, and that using the storage amount ratio.

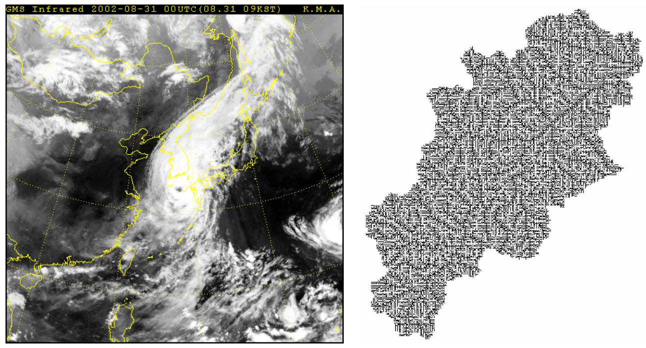

Figure 3. Satellite image of Typhoon Rusa, 2002 (left figure), and the produced flow direction map of Gam-cheon Basin, Korea, for CDRMV3 simulation (right figure)

4. Case Study of Typhoon Rusa, 2002

The developed real-time forecasting algorithm is to be applied on Gam-cheon Basin, South Korea with Typhoon Rusa flood events, which was one of the most disastrous floods in 2002. Radar data of Kunsan radar station and geographic data of Gam-cheon Basin is under processing for applying the developed algorithm.

5. References

[1] Shiiba, M., Takasao, T., and Nakakita, E.: Investigation of short-term rainfall prediction method by a translation model, Proc. 28th Annual Conf. on Hydraulics, JSCE, 423-428, 1984

[2] Kim, S., Tachikawa, Y., and Takara,K.: Ensemble rainfall-runoff prediction with radar image extrapolation and its error structure, Annual journal of hydraulic engineering, JSCE, No. 50, 2006 (in printing)

[3] Kojima, T. and Takara, K.: A grid-cell based distributed flood runoff model and its performance, Weather radar information and distributed hydrological modeling (Proceedings of symposium HS03 held during IUG2003 at Sapporo, July 2003), IAHS Publ. No. 282, 234-240, 2003

[4] Kim, S., Tachikawa, Y., and Takara,K.: Real-time prediction algorithm with a distributed hydrological model using Kalman filter, Annual journal of hydraulic engineering, JSCE, No. 49, 163-168, 2005