Precipitation prediction methods developed by the Kansai Electric Power Co., Inc.

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Abstract

In the Asahi Dam of the Kansai Electric Power Co., Inc., a sediment bypass system has been operated since 1998. It was constructed as drastic countermeasure facility for the long-term turbidity and the rapid sedimentation progression triggered by the hillside collapse due to the severe flood in 1990. Its effect on the long-term turbidity phenomenon and the dam sedimentation progression is confirmed. Basically, the sediment bypass is operated at the time of the flooding by considering the meteorological information or the flooding prediction. The Kansai Electric Power Co., Inc. is developing the meteorological prediction technology that contributes widely to the reliable operation of the bypass tunnels, and this paper introduces these technologies.

Keywords: precipitation prediction, weather radar, wavelet analysis

1 Background of the development

The history of the original precipitation prediction methods development in Kansai Electric Power Co., Inc. can be called the history of the disaster in the dam basin which Kansai Electric Power manages.

The inundation damage with the flood occurred by the typhoon No. 19 in 1990 that attacked the south district, mainly the Hiki River basin, in September 1990. In the Tonoyama Dam, a dam for exclusive use of the generation of Kansai Electric Power, they managed and succeeded to control the flood by certain operation while they desired official regulation rules. From this experience, we recognized the need of the rain-flood prediction that had higher precision in the south district where typhoon hits frequently. We developed an original rain prediction technique called "super short time rain prediction technique" to predict ahead by update for three hours for five minutes. Because the development short time rain predictive information of this patent technique provided at first by the Meteorological Agency was only three hours ahead prediction of the update for one hour, the development of this technique was epoch-making.

The torrential rain that attacked the Hokuriku district from July 11, 1995 caused unprecedented great damage for generation facilities of Kansai Electric Power Co., Inc. located in the Kurobe River. With this disaster, we judged that weather information delivered by the Meteorological Agency is not enough for dam management in the

Kurobe River basin where local heavy rainfall events occurs frequently, and analyzed the rain, the weather characteristics of the mountains area in detail and developed "the hybrid rain prediction technique" which can predict precipitation until 6 hours ahead with high accuracy. Kansai Electric Power Co., Inc. has developed rainfall and inflow prediction system for Kurobe River with the combination of hybrid prediction system and distribution type outflow prediction model. And the outputs of the system are used in the judgement of flushing sediment in the Dasidaira Dam.

In recent years Ministry of Land, Infrastructure and Transport maintains the precipitation high-resolution radar observation network observing (XRAIN) of the 250 m mesh by update for one minute for the purpose of watching a frequent local heavy rain and applies it in after 2010. Therefore we utilized observation data of XRAIN, and Kansai Electric Power Co., Inc. developed "the wavelet precipitation prediction technique" corresponding to the sudden flood caused by the local heavy rain in the dam basin.

In the operation of sediment bypass tunnel, bypassing flows at the time of high turbidity is a key of the efficiency. The prediction of inflow sediment by sudden flood with local heavy rain is necessary to carry out appropriate operation of bypass tunnel. In this report, we introduced the wavelet precipitation prediction technique and applied this technique to a specific site.

2 Precipitation prediction method based on wavelet analysis

2.1 Characteristics of precipitation phenomena

When a low pressure and a front pass through, it drizzles from several hours to several ten hours in time and from several tens to several hundred kilometers in space. On the other hand, the summer shower causes very heavy localized precipitation within several ten minutes and sometimes causes a disaster. Thus, precipitation characteristics differ in features such as types and duration of rainfall depending on the horizontal spread of rainy area (rainfall scale). The rainfall phenomena can be classified into large scale which is larger than tens of kilometers or small scale which is smaller than tens of kilometers. The characteristics are shown in Table 1.

In this study, we have developed a new nowcasting method to improve accuracy of prediction for localized heavy rainfall, considering the difference of movement characteristics between large and small scale precipitation distribution. In traditional short term precipitation prediction method, including the precipitation Nowcast of the Japan Meteorological Agency, the difference has not been considered.

As large and small scale rainfall phenomena differ in time scales, by separating small scale precipitaton distribution from total one, and are separated from each other, the improvement of precipitation prediction accuracy is expected.

Table 1: Characteristics of convective and stratiform precipitation

	Large Scale	Small Scale
Example of phenomena	Stationary front, low pressure	Localized heavy rainfall
Spatial scale	Larger than 100 km	Few km – few 10 km
Time Scale	Longer than few hours	Few 10 minutes – few hours
Rainfall intensity	Weak (less than 20 mm/hour)	Strong (sometimes larger than 100 mm/hour)
Movement of precipitation distribution	Mainly moved by wind at height of 3–5 km	Mainly moved by wind at hight of 3–5 km, and affected by wind and humidity at height of <1 km

2.2 Precipitation prediction method

We have developed a precipitation prediction method, in which observed precipitation distribution is divided into large and small. Calculation flow of the developed precipitation prediction method is shown in Fig. 1.

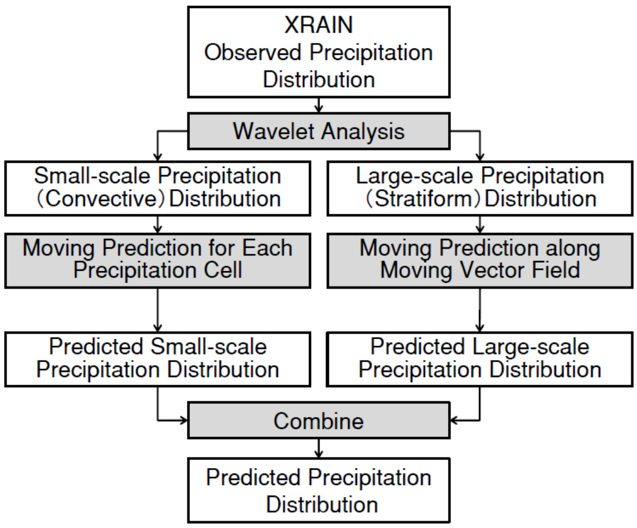

Fig. 1: Calculation flow of the developed precipitation prediction method

2.2.1 Data

In Japan, Ministry of Land, Infrastructure, Transport and Tourism (MLIT) provides X-band polarimetric (multi parameter) RAdar Information Network (XRAIN) data experimentally from 2010. XRAIN data is used in this study. Specifications of XRAIN data are as follows. Spatial resolution is 250 m and time resolution is 1 minute.

2.2.2 Development of a method to separate precipitation distribution

Wavelet analysis is applied to divide precipitation distribution. The wavelet analysis is a method of the frequency analysis like the Fourier transform. By the method, horizontal precipitation distribution can be break down to an ingredient of 1 km, 2 km, 4 km, and so on. The small scale distribution gained by the wavelet analysis is defined as "small-scale precipitation distribution (SPD)". The distribution, where SPD is subtracted from original distribution is defined as "large-scale precipitation distribution (LPD)", which is considered to be stratiform precipitation distribution. The separation scale is fixed to 16 km. The border of large and small scale of Table 1 is considered to be 20 km from meteorological view, and 16 km is considered to be reasonable.

2.2.3 Precipitation prediction method suitable for horizontal scale

For SPD and LPD, we can consider movement of the precipitation distribution respectively. Predicted SPD and LPD are merged to gain the final predicted precipitation distribution. As movement characteritics of precipitation distrbution differs with SPD and LPD, we developed adequate prediction method for each distribution.

a) The small-scale prediction method

A small-scale rainfall is occured by cumulonimbus, the motion of precipitation distribution is approximately the same as that of cumulonimbus. First, the precipitation distribution surrounded by a line of rainfall intensity 2 mm/hr is regarded as a cluster, the small-scale distribution was divided. TREC method (Rinehart 1979) is used to identify moving vector of each precipitation cell in small scale precipitation distribution. Small scale precipitation distribution of initial time, that of 2 minutes past, and 4 minutes past are used for the identification. Each precipitation distribution is assumed to move with the identified vector turing the prediction lead time.

b) The large-scale prediction method

Large-scale rain clouds are drived by the wind of middle atmosphere. We estimated precipition advection vector field. To identify the moving vector field of large scale precipitation distribution, analysis area is divided into 4 areas in the horizontal direction of 2×2. For each divided area, moving vector is identified to minimize R.M.S.E. by TRED method (Laroche and Zawadzki 1995). LPD of initial time, that of 6 minutes past and 12 minutes past are used for the identification. The vector is assumed to be moving vector of the center of the area, and vector of every observation point is determined by linear interpolation.

2.3 Application of the developed method

We applied the developed precipitation prediction method to an actual rainfall event and confirmed its applicability. We compared the developed precipitation scale separating method (abbreviated as SPRT) and conventional non-separating method (abbreviated as

CONV), and verified effect of the separation method to prediction accuracy. Fig. 2 shows the results of separating into large and small scale components of observation data at 6:45 on September 8, 2010. It can be seen that small cale precipitation distribution corresponding to individual cumulonimbus clouds are extracted.

Fig. 3 shows the predicted precipitation distribution for 20 minutes ahead of the predicted at 6:45 on September 8, 2010, and observed precipitaion of the predicted time. In Fig. 3, time series of observed and predicted precipitation is also shown.

The heavy precipitation distribution shown by red circle in Fig. 3 moved to the east was combined with another heavy precipitation distribution. The similar movement and combination are predicted by SPRT. On the other hand, the heavy precipitation distribution is predicted to move to the northeast direction and combination with another heavy precipitation distribution is not predicted by CONV. From the comparison of time series of precipitation, it can be seen that predicted precipitation by SPRT is similar to observed precipitation than that by CONV.

Fig. 4 shows time series of R.M.S.E. of predicted precipitation distribution to observed distribution calculated in black square frame shown in left map of Fig. 4. Compared to CONV (blue line), SPRT (red line) shows good accuracy during 0–30 minutes lead time.

From these, it was found that the accuracy of precipitation prediction becomes higher by extracting convective characteristics precipitation, and performing a prediction in consideration of the difference of the movement characteristics.

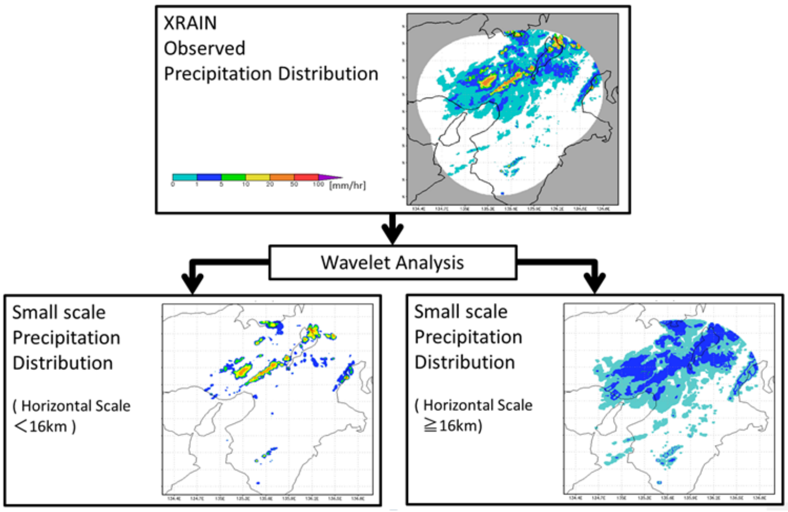

Fig. 2: An example of separation of precipitation distribution by wavelet analysis

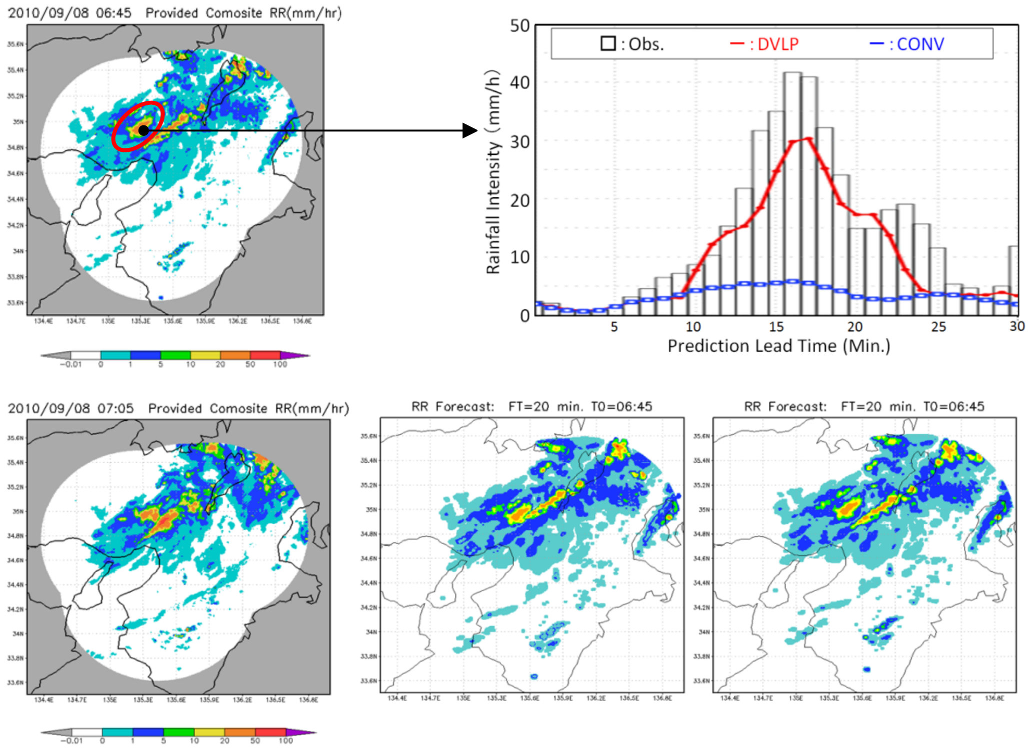

Fig. 3: Comparison of observed and predicted precipitation (prediction initial time: 2010.9.8 6:45(JST))
Upper left: Observed precipitation distribution at prediction initial time.
Upper right: Time series of observed and predicted rainfall intensity at ● in upper left map
Lower: Precipitation distribution 20 minutes after prediction initial time.
(left: observed, middle: predicted by SPRT, right: predicted by CONV)

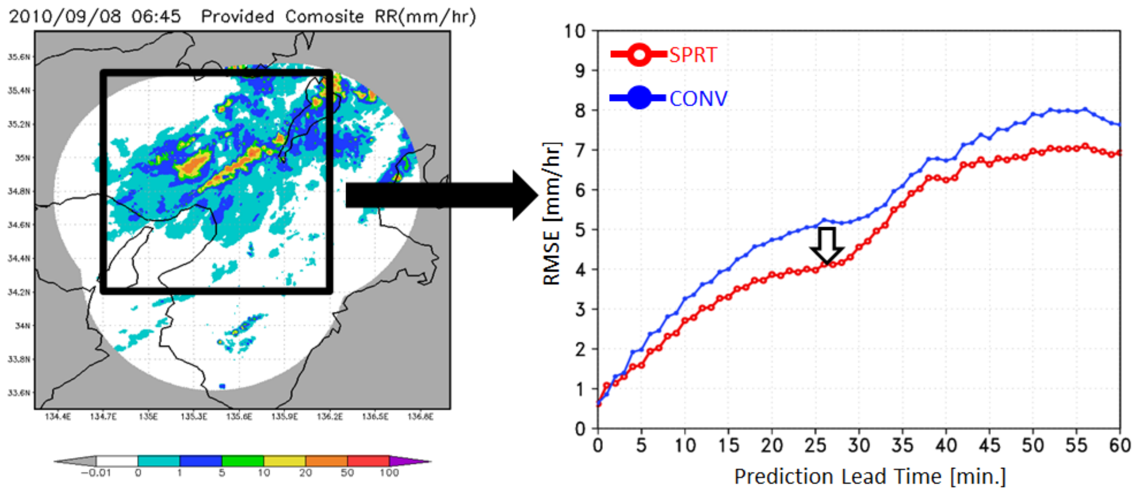

Fig. 4: Comparison of time series of RMSE (prediction initial time: 2010.9.8 6:45(JST), R.M.S.E. analysis area: black square in left map)

3 Conclusion

We have developed a precipitation prediction method, in which high resolution radar data is used and the difference in movement characteristics of precipitation phenomenon for spatial scale is considered. Through application to actual heavy rain events, it was found that precipitation prediction accuracy improves with the developed method. We will continue to evaluate the development method by applying to heavy rainfall cases, plan to construct a sediment discharge prediction system together with analysis of sediment discharge actual results with rainfall, and develop technologies that should contribute to the appropriate operation of the sediment bypass.

For the purpose of contributing to the security of hydraulic power generation facilities and effective use, the Kansai Electric Power Co., Inc., is now developing precipitation prediction method by using Phased Array Weather Radar (PAWR). PAWR is the latest weather radar which can observe high density 3 dimensional precipitation with 30 seconds interval. Furthermore, we continue development, the improvement of the solar radiation prediction system in late years to grasp the generation quantity with the photovoltaic power generation facilities in the tendency to increase exactly, and to predict it. The development of the system aims at the realization of stability and effective power supply by managing various generation facilities such as heat, water power, the light of the sun ideally, and the result is utilized in the spot of the electric power system use. We will continue the utilization in the electricity spot of the development of the weather prediction technology to be necessary to realize security and stable power supply and the development result in future.

References

Rinehart, R.E. (1979). Internal storm motions from a single non-Doppler weather radar, NCAR/TV-146+STR.

Laroche, S., Zawadzki, I. (1995). Retrievals of Horizontal Winds from Single-Doppler Clear-Air Data by Methods of Cross Correlation and Variational Analysis. *J. Atmos. Oceanic Technol.*, 12, 721-738.

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