The Operational Very Short Range Forecast of Precipitation and its Hydrological Applications in South Korea

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1. Introduction

The Very-Short-Range Forecast of Precipitation(VSRF) system has been operated by the Japan Meteorological Agency and provides forecasts for lead times up to 6 hours with a spatial resolution of 5 km. The displacement vectors for forecasts up to 3 hours are derived using a pattern matching method that takes into account orographic enhancement and dissipation of rain. To extend the lead time up to 6 hours the extrapolation method is merged with forecasts derived from a mesoscale numerical weather prediction model depending on the accuracy for both forecasts over the last few hours.

National Institute of meteorological research in Korea Meteorological Administration(KMA) has been modifying and optimizing the JMA VSRF model to test the feasibility as a short-time forecasting tool of precipitation for Korea since 2003.

A brief description of modified KMA VSRF and the results of performance test are given in section 2 and 3, respectively. In section 4, it is shown the verification of mean areal precipitation forecasted by VSRF model for the hydrological application and evaluated the performance of the hydrological runoff model when the forecasted precipitation field(6 hour ahead) by VSRF model is used input data.

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2. Overview of VSRF model

The radar data from 11 operating radar sites, 600 rain gauges data near radar and the outputs of KMA regional mesoscale model, RDAPS(Regional Data Assimilation and Prediction System), are used as input data of VSRF model. The VSRF model consists of two main processes which are the quantitative radar precipitation estimation and the forecast of precipitation by simple extrapolation method up to 3-hour and then merging with numerical prediction model for 6-hour, respectively.

Table 1. Description of VSRF initial data.

Parameter	Time	Horizontal resolution (grid dimension)
Topography	constant	5 km×5 km (160×160)
700 hPa U, V wind	0 hour	
900 hPa U, V wind	0 hour	
900 hPa Relative Humidity	0 hour	
900 hPa Temperature	0 hour	
Radar QPE	-3, -2, -1, 0 hour	
Radar echo-top height	0 hour	

2.1 Quantitative radar precipitation Estimation

KMA has been improved the Window Probability Matching Method(WPMM, Rosenfeld et al., 1993) to estimate quantitative precipitation intensity from radar reflectivity. The WPMM based radar quantitative precipitation estimation system called RAR (Radar-Aws-Rainrate) with 1km resolution and the verification system have been operating every 10-minute real time (Figure 1). Therefore the initial radar-AMeDAS precipitation field in JMA VSRF mode was replaced as the radar precipitation by WPMM in KMA.

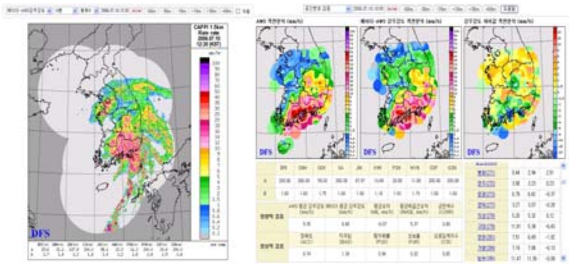


Figure 1. Radar QPE and verification system based on WPMM and verification system on real-time.

WPMM drives the Z-R relationship using probability density function between radar reflectivity and measured precipitation intensities at the same window as shown in figure 2.

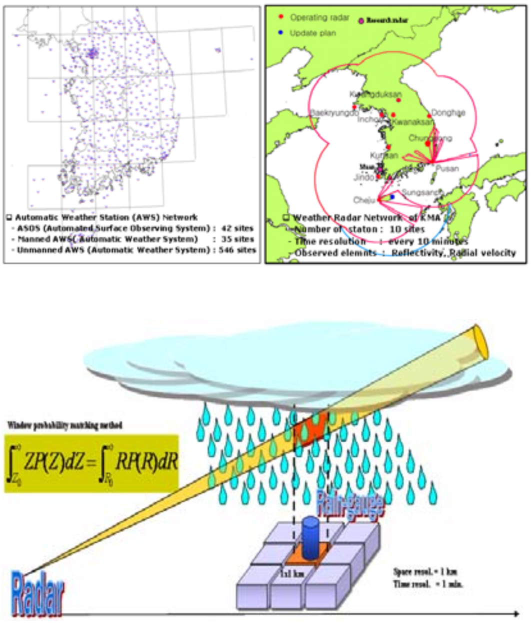


Figure 2. (upper) Rain gauge and radar network in KMA and (bottom) The concept of data sampling to match the probability matching between radar reflectivity and measured precipitation intensities.

Figure 3 shows the schematic diagram illustrating the process of getting the Z-R relationship by WPMM and an example relationship.

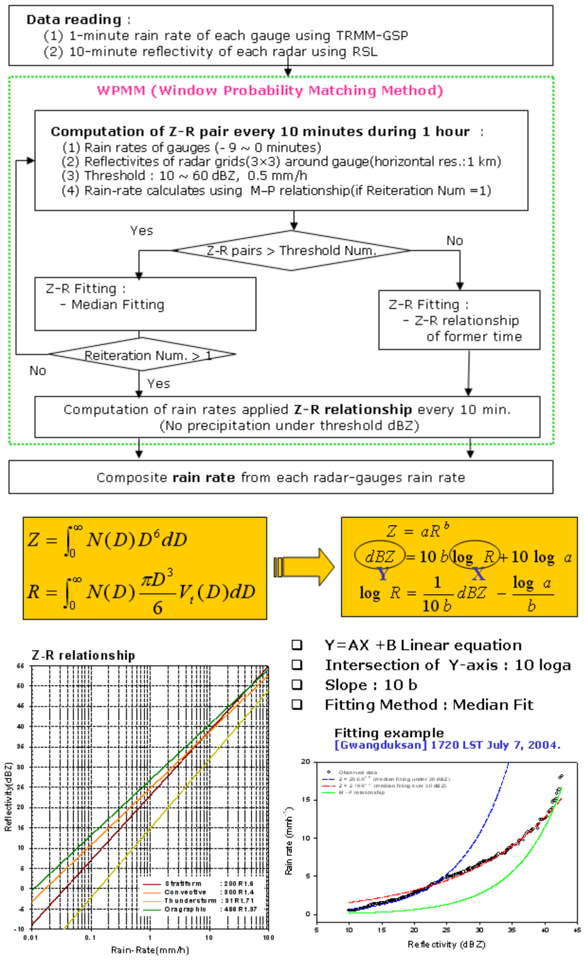


Figure 3. The schematic diagram illustrating the process of getting the Z-R relationship by WPMM and the example relationship for Gwanduksan radar at 1720 LST July 7, 2004.

The accuracy of radar precipitation intensity estimated by this method has shown to be better than the one by conventional power-law relationship of Marshall and Palmer ($Z=200R^{1.6}$) as shown in Table 2.

Table. 2 The verification score of QPE by WPMM and M-P relationship on July 12, 2006 (threshold 0.1mm/hr).

	Estimated mean (mm/hr)	Mean error (mm/hr)	RMSE	R^2	Bias Score
WPMM	6.68	-1.25	5.77	0.80	0.70
M-P	4.10	-3.92	7.67	0.70	0.30

2.2 Forecast process of Precipitation

The forecast of precipitation follows the forecasting process of JMA VSRF model and there is no big difference with the 2001 JMA VSRF version. It was made only up to 3-hour forecast by a simple extrapolation method which uses pattern matching technique to obtain the movement information of precipitation system and extended the forecasting time as adopting the blending method with numerical model up to 6-hour. It also Includes the enhancement and dissipation process of precipitation systems by orographic effect based on the concept of seeder-feeder model(Browning and Hill, 1981). Figure 4 shows the flowchart of forecasting and blending process with numerical prediction model in VSRF model. The detail description of these processes shows an introduction of JMA VSRF model in Kunitsugu *et al*.(2001).

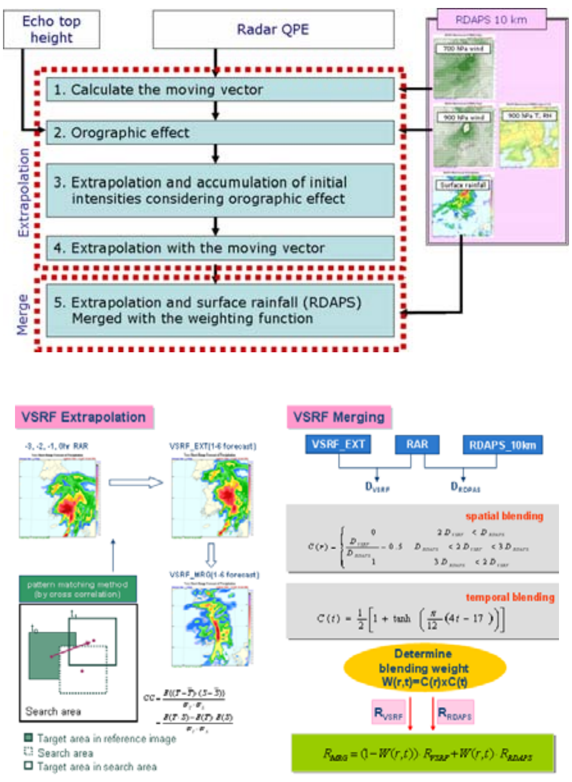


Figure 4. The flowchart of (a) forecasting and (b) blending process with numerical prediction model in VSRF model.

3. Verifications of VSRF model

The VSRF model has been improved by accepting the blending method between the nowcasting and mesoscale model to overcome the rapid decline of performance of simple extrapolation model. The blending scheme between the VSRF and RDAPS (Regional Data Assimilation and Prediction System) is applied for the first 4-6 forecast hour and tested during the 2006 summer. The performance of the blended VSRF model with RDAPS model has shown to be better than that of the simple extrapolation VSRF model(Figure 5).

KMA is still continuing the development of VSRF model for higher predictability of precipitation. The current version of VSRF model has been operating as the guidance of short-time precipitation forecast for KMA forecasters every 1 hour on real time(Figure 6).

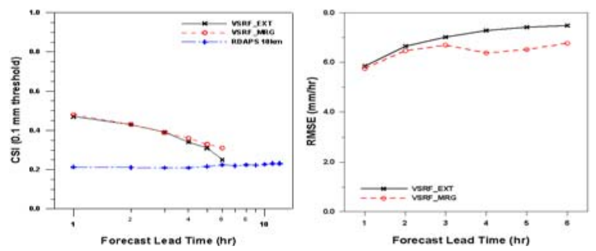


Figure 5. CSI and RMSE of the forecasted (solid), merged (dash), and RDAPS 10 km (dash-dot) precipitation versus the observed (rain gauge) one during the summer period from June to August in 2006.

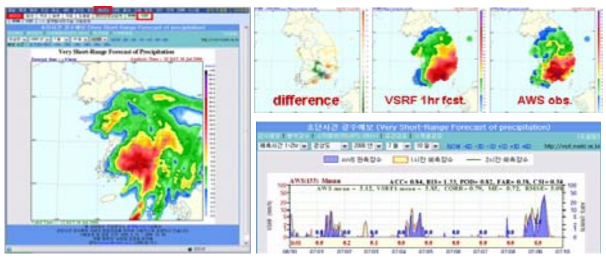


Figure 6. The operational VSRF in KMA and its verification system on real time since 2006.

4. Hydrological Application for runoff model

4.1 Verification of mean areal precipitation

Verification of mean areal precipitation forecasted by VSRF model for the hydrological application was employed at the Kyoung-An river basin(127°16′47″~127°14′40″E, 37°11′08″~37°21′01″N) with basin areal in 568 km^2 in figure 7.

The mean areal precipitation(MAP) between VSRF model and rain gauge is compared for 3 cases (case 1: summer rainy, case 2: heavy rainfall, case 3: typhoon case) in 2003. The VSRF model forecasts the precipitation well up to 2 hour.

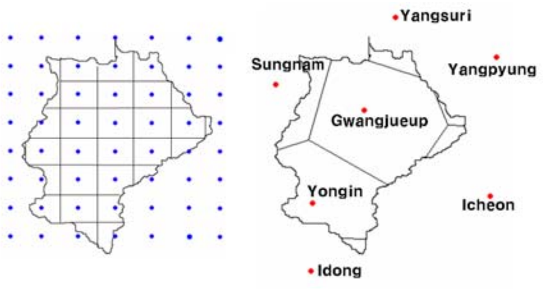


Figure 7. Thiessen of Kyoung-An river basin

It is compared the observed and forecasted mean areal precipitation in Kyoung-An river basin in figure 8. The precipitation tendency within 2 hour lead time relatively conforms to the observed ones, but it seemed to show the tendency of time-lag to the observed one afterward.

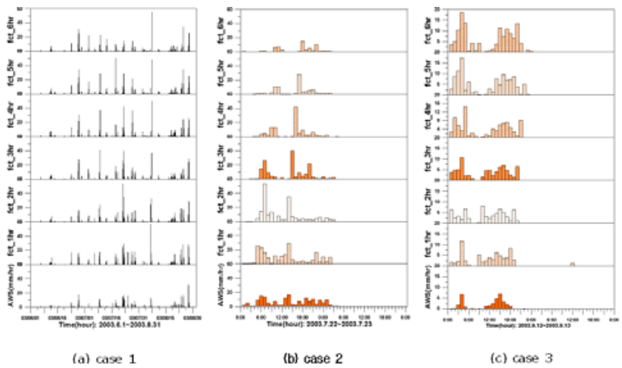


Figure 8. Mean areal precipitation in Kyoung-An river basin at each case.

Figure 9 and 10 shows the Critical Successive Index(CSI) and other verification factors of MAP forecasted by VSRF model for 3 cases at threshold values of 0.1, 1.0 and 5.0 mm/hr, respectively.

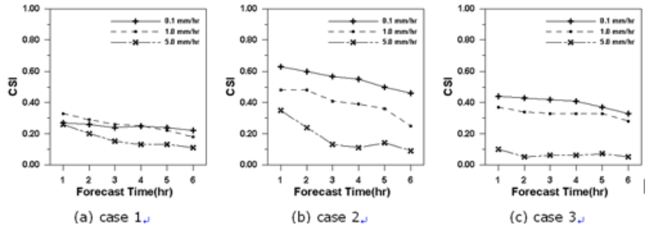


Figure 9. CSI of areal precipitation forecasted by VSRF model and measured precipitation at rain gauge in Kyoung-An river basin at 3 cases.

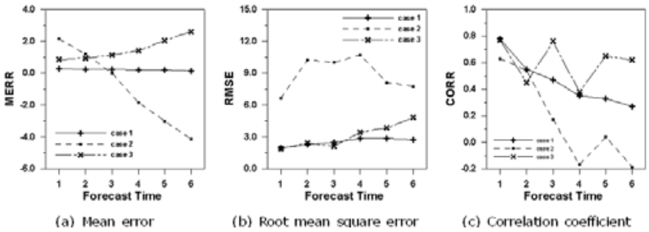
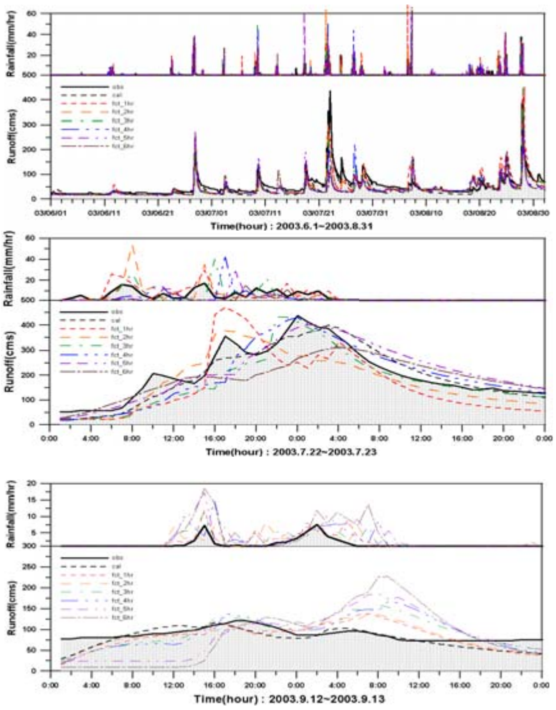


Figure 10. Same as Figure 7 but for (a) mean error, (b) RMSE, and (c) correlation coefficient.

4.2 Evaluation of hydrological runoff model

The forecasted precipitation field(6 hour ahead) by VSRF model is used input data of the hydrological runoff model, National Weather Service River Forecast Sytem (NWSRFS). The model performance is evaluated to the same cases as the verification of the mean areal precipitation. Figure 11 presents the observed and simulated runoff and statistical results for model verification for each period. The correlation coefficient between hydrological runoff model using precipitation field forecasted(6 hour ahead) by VSRF model and observed runoff data is up to 0.6 within 3 hour lead time during heavy rainy day. It represents that the VSRF of precipitation is very useful for water resources application.



Statistic	case 1(2003.6.1~2003.8.31)							
	OBS	AWS	+1hr	+2hr	+3hr	+4hr	+5hr	+6hr
Peak Flow (cms)	438.00	424.62	452.22	367.83	447.43	333.03	276.50	325.09
Peak Time (hr)	1248	1250	2118	2112	2112	2113	2114	2115
ave. of Flow (cms)	52.72	43.75	48.68	41.64	41.57	40.58	39.01	37.56
std. of Flow (cms)	42.44	44.55	46.41	34.59	35.66	33.61	29.17	29.77
Mean Error (cms)	-	-8.98	-4.04	-11.08	-11.15	-12.14	-13.71	-15.17
RMSE (cms)	-	17.04	26.17	27.07	27.52	32.82	34.90	38.05
Correlation Coef.	-	0.95	0.83	0.81	0.81	0.70	0.66	0.58

Statistic	case 2(2003.7.22~2003.7.23)							
	OBS	AWS	+1hr	+2hr	+3hr	+4hr	+5hr	+6hr
Peak Flow (cms)	438.00	400.19	471.39	377.48	431.05	431.25	401.80	311.15
Peak Time (hr)	24	27	17	17	23	24	25	28
ave. of Flow (cms)	207.25	200.33	163.02	175.55	175.71	200.24	217.36	191.74
std. of Flow (cms)	105.44	112.91	128.41	106.48	111.01	119.73	107.97	74.80
Mean Error (cms)	-	-6.92	-44.23	-31.70	-31.54	-7.0	10.11	-15.51
RMSE (cms)	-	38.42	83.08	61.46	51.53	53.31	54.51	68.18
Correlation Coef.	-	0.94	0.83	0.88	0.93	0.90	0.87	0.78

Statistics	case 3(2003.9.12~2003.9.13)							
	OBS	AWS	+1hr	+2hr	+3hr	+4hr	+5hr	+6hr
Peak Flow (cms)	121.00	117.50	138.26	137.30	159.17	168.11	185.04	227.11
Peak Time (hr)	18	16	31	31	32	33	32	33
ave. of Flow (cms)	87.73	78.98	83.69	86.35	96.42	93.93	87.57	86.04
std. of Flow (cms)	13.91	23.05	29.89	28.70	35.29	38.29	52.15	66.05
Mean Error (cms)	-	-8.75	-4.04	-1.38	8.69	6.20	-0.16	-1.69
RMSE (cms)	-	18.03	26.18	25.96	33.54	36.56	52.67	66.48
Correlation Coef.	-	0.74	0.50	0.43	0.40	0.34	0.10	0.08

Figure 11. Observed and simulated runoff and statistical results for model verification for each period.

5. Conclusions

The National Institute of Meteorological Research has been developing and operating the Very Short Range Forecast of precipitation(VSRF) model supported from Japan Meteorological Agency (JMA) since 2003. KMA is hourly operating two kinds of VSRF models based on the simple extrapolation version and the blended version with meso-scale numerical prediction model to monitor the performance. Both are one hour forecast up to 6 hours ahead with 5km resolution on real-time mode. The precipitation analysis field of VSRF is derived from the radar quantitative precipitation estimation system that is automatically calculating by Window Probability Matching Method using the composite radar reflectivity from 11 KMA radars and highly densed rain gauge data. For blended version, the concept of pattern distance and the transformed hyperbolic tangent function are employed for the spatial and temporal blending scheme. The spatial blending technique of forecasted precipitation plays a significant role of compensating for the regionally mistaken forecast fields. During the heavy rainfall the performance of blended VSRF seemed to be better than that of simple extrapolation.

For the hydrological application of precipitation forecast field of VSRF model, it is performed the hydrological verification of VSRF model(only extrapolation version) and combination with rainfall-runoff model (PC version, National Weather Service River Forecast System) in Kyoungan River Basin. It is compared the mean area precipitation between VSRF and Rain gauge. The correlation coefficient between hydrological runoff model using precipitation field forecasted(6 hour ahead) by VSRF model and observed runoff data is up to 0.6 within 3 hour lead time during heavy rainy season. It represents that the VSRF of precipitation is very useful for water resources application.

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