## 5.4 Very-short-range Forecasting of Precipitation

JMA has been routinely operating a fully automated system for semi-hourly analysis and very-short-range forecasting of precipitation since 1988 to provide products for monitoring and forecasting local severe weather. The products are :

(a) Analysis of precipitation called "Radar-Raingauge Analyzed Precipitation" (hereafter R/A) based on the observations by radars and the raingauge measurements by the Automated Meteorological Data Acquisition System (hereafter AMeDAS) in JMA and the other available data, for example raingauges by local governments,

(b) Semi-hourly forecasts of 1-hour accumulated precipitation called "Very-Short-Range-Forecast of precipitation" (hereafter VSRF) based on extrapolation and forecast by Meso-scale Model (MSM, See 4.5). The forecast time of VSRF is from 1 to 6 hour.

In March 2006, JMA changed the specification of these products. The resolution of the R/A was enhanced from 2.5km x 2.5km mesh to 1km x 1km mesh. For the VSRF, the resolution was enhanced from 5km x 5km mesh to 1km x 1km mesh.

These products are made available in about 20 minutes after observation time every half hour. They are transmitted in the digital data to local meteorological observatories, and the local governments and broadcasting stations which are responsible for disaster prevention.

### 5.4.1 Analysis of precipitation (R/A)

Twenty radars and approximately 8,500 raingauges, which consist of 1,300 AMeDAS stations and 7,200 raingauges by the other organizations, provide observational data for the R/A. These data are combined to benefit from advantages of both facilities: the advantage of the radar is its high resolution in space and that of raingauge is its accuracy of precipitation measurement.

On each radar site, the power scattered from rain particles is received and digitized by an automatic data processing system called "weather Radar Observation and Processing System (ROPS)". A ground clutter is automatically removed through a Moving Target Indicator (MTI) filter by ROPS. A Z-R relationship as follow is used for the conversion from the radar reflectivity factor to rainfall intensity:

$$Z = 200 \times R^{1.6} \tag{5.4.1}$$

where Z is radar reflectivity and R is rainfall intensity.

The horizontal resolution of the intensity data is 1.0km. One-hour accumulated radar precipitation amounts are calculated from the rainfall intensities.

The one-hour accumulated precipitation amounts by radar observation are usually different from those observed with raingauges. The radar precipitation amounts are calibrated into more accurate precipitation using the raingauge precipitation data (Makihara 2000). First, calibration factors over the entire detection range of each radar are calculated by comparing the radar precipitation of the multiple radars and raingauge data. When comparing radar precipitation, the difference of radar beam height is taken into account. Then the estimated calibration factor is modified at each grid over land using raingauge data. For the grid within which no raingauges are contained, the calibration factors are interpolated from those with raingauges. Composition of each radar's calibrated precipitation into a nationwide chart is made by the maximum method, in which the largest value is selected from the several different radar observations on the same grid. A schematic diagram of this procedure is shown in Figure 5.4.1.

### 5.4.2 Forecasting of precipitation (VSRF)

Two methods are used for VSRF. One is the extrapolation of movements of the analyzed precipitation systems. In the course of extrapolation, development and decay of the precipitation systems due to orographic effects are taken into account. The other is the forecast of precipitation by MSM, which is available in about one and a half hour later from its initial time, eight times a day (every three hours). The extrapolation forecasts are more skillful than the MSM forecasts at first, but they rapidly lose skill. On the other hand, the skill of the MSM forecasts degrades gradually and becomes comparable with the extrapolation forecasts after a few forecasting hours. Therefore the so-called "merging technique" was introduced. It is essentially the weighted-averaging of those two precipitation forecasts. For the first one hour, the merging weights are set nearly zero for the MSM forecasts, so the products are almost the same as the extrapolation forecasts. After that, the merging weights for the MSM forecasts increase with forecast time to the amount that is determined from the skill of the MSM forecasts and the extrapolation forecasts. A schematic diagram of this procedure is shown in Fig. 5.4.2.

(a) Extrapolation forecasts

The calibrated precipitation intensity, which is obtained in the course of the precipitation analysis (Section 5.4.1), is used as the initial value of the forecast. A time step of the forecast is two minutes and the forecasted precipitations are accumulated to produce hourly forecasts up to six hours.

The extrapolation vectors (movement vectors of precipitation systems) are evaluated by a generalized cross correlation method, comparing the location of the precipitation systems at the initial time with those at 0.5 1, 2 and 3 hours before.

As the seeder-feeder mechanism is assumed to work in the regions of orographic updraft, the precipitation systems are allowed to develop in the course of extrapolation over such regions. Precipitation systems that have passed across mountains higher than its echo top height are decayed, when the following two conditions are satisfied:

(1) orographic downslope motion of the rain system is expected from the low-level wind of MSM,
(2) the direction of the rain system movement or that of 700hPa wind by MSM is nearly parallel to that of 900hPa wind by MSM.

(b) Merging technique

First, the relative skill of the extrapolation forecast and the MSM forecast are estimated. The extrapolation forecast from three hours before is verified against the current analysis. For the MSM forecast, the latest available forecast is verified with the current analysis. The relative reliability coefficient $C_{RR}$ is defined as follows:

$$C_{RR} = \begin{cases} 0 & if \quad 2D_{EX} < D_{MSM} \\ \dfrac{D_{EX}}{D_{MSM}} - 0.5 & if \quad D_{MSM} < 2D_{EX} < 3D_{MSM} \\ 1 & if \quad 3D_{MSM} < 2D_{EX} \end{cases} \tag{5.4.2}$$

where $D_{EX}$ is the 2-dimensional pattern distance, or 2-dimensionally extended Levenshtein distance, between the extrapolation forecast and the analysis, and $D_{MSM}$ is the 2-dimensional pattern distance between the MSM forecast and the analysis.

Then, the relative weight of the extrapolation forecast $C_{EX}(T)$ is determined by $C_{RR}$ and the statistically determined function $C(T)$ indicated at merge process in fig. 5.4.2, where $T$ denotes the forecast time in hour:

$$C_{EX}(T) = 1 - C_{RR} \cdot (1 - C(T)) \tag{5.4.3}$$

Finally the merged forecast $R_{MRG}(T)$ is calculated with the following equation:

$$R_{MRG}(T) = C_{EX}(T) \cdot R_{EX}(T) + (1 - C_{EX}(T)) \cdot R_{MSM}(T) \tag{5.4.4}$$

where $R_{EX}(T)$ denotes the extrapolation forecasts of precipitation at the forecast time $T$, and $R_{MSM}(T)$ denotes the MSM forecasts of precipitation from the latest initial time at the same valid time $T$.

### 5.4.3 Example and verification score

An example of the R/A and VSRF is shown in Figure 5.4.3. The R/A in the Kyushu region, southwestern area of Japan at 18UTC 21 July 2006 is shown in the left panel (a), and the 3-hour forecast of VSRF at the same valid time, i.e. its initial time is at 15UTC 21 July 2006, is shown in the right panel (b). The intense rain band is well forecasted.

Accuracy of VSRF has been statistically verified with the Critical Success Index[1] (CSI). Forecasts are compared with precipitation analysis after both fields are averaged in 20km x 20km grids. Threshold value is set as 1mm/hr. Indices from 1-hour to 6-hour forecasts for October 2006 are shown in Figure 5.4.4, together with those of the extrapolation, MSM, and the persistence forecasts.

It can be seen that the scores get worse as forecast time gets longer. Up to three hours, the extrapolation forecast keeps its superiority to the MSM, but the relationship of them become reverse after four hours, while VSRF behaves best performance through all forecast times.

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[1] The CSI is the number of correct "yes" forecasts divided by the total number of occasions on which that event was forecast and/or observed. It is also cited as “Threat Score”.

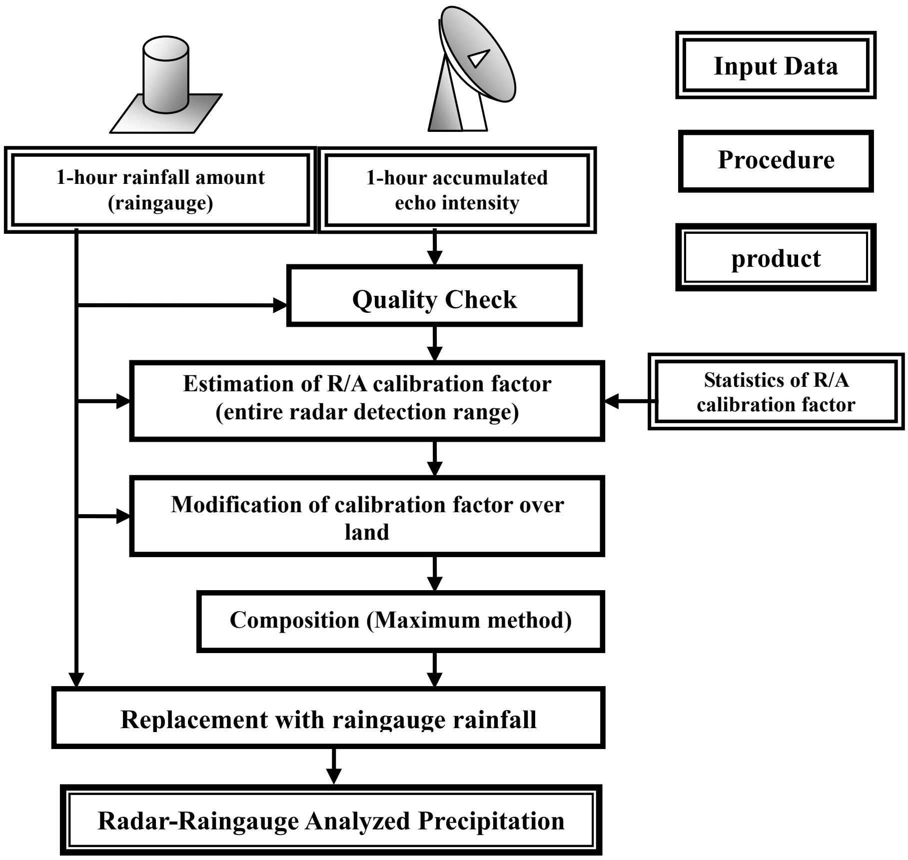


Figure 5.4.1 A schematic diagram of the "Radar- Raingauge Analyzed Precipitation" analysis

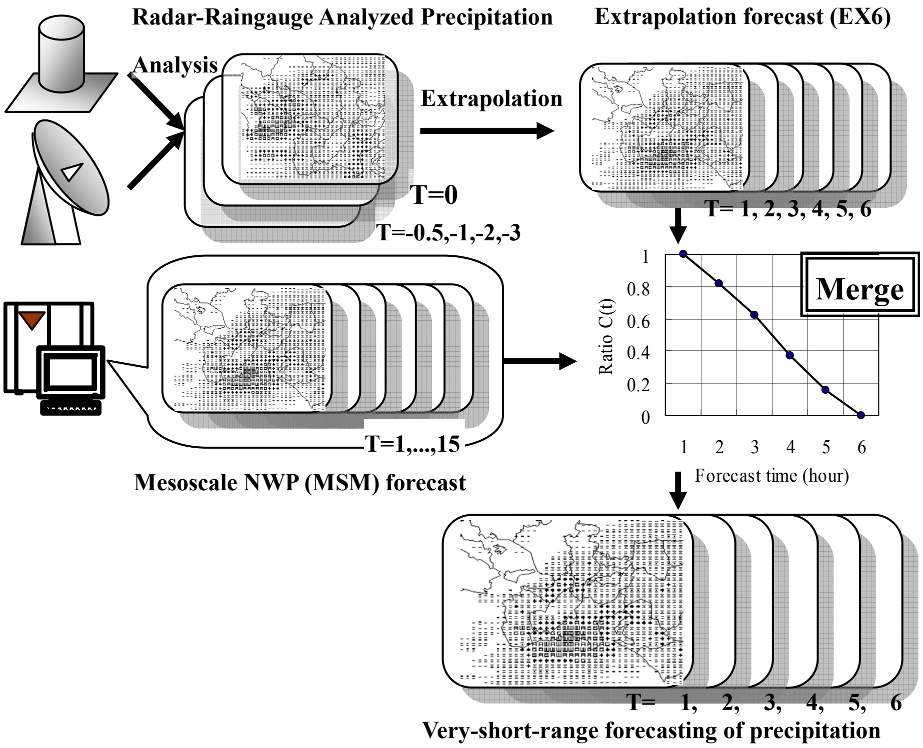


Figure 5.4.2 A schematic diagram of the very-short-range forecasting of precipitation

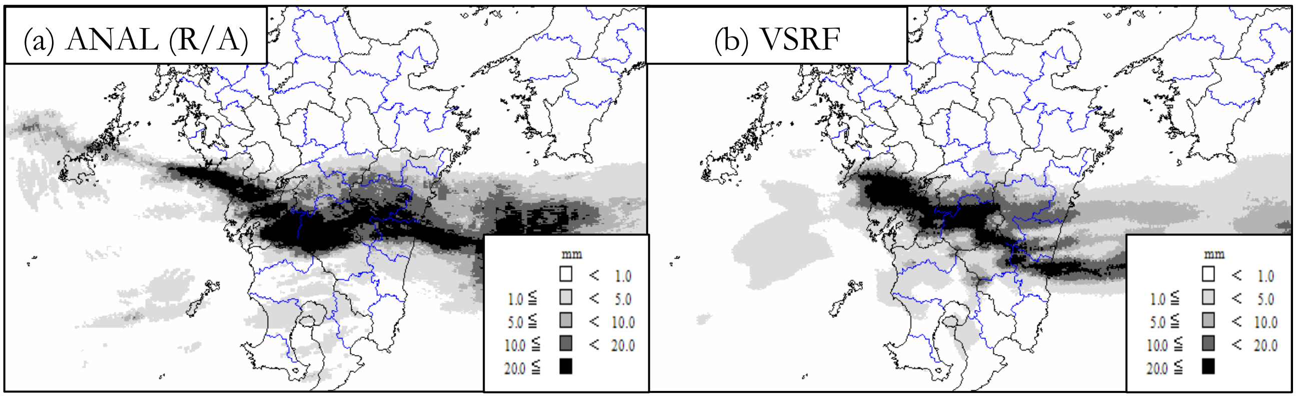


Figure 5.4.3 An example of (a) the Radar-Raingauge Analyzed precipitation at 18UTC 21 July 2006 and (b) the 3-hour forecast of precipitation of VSRF at the same valid time

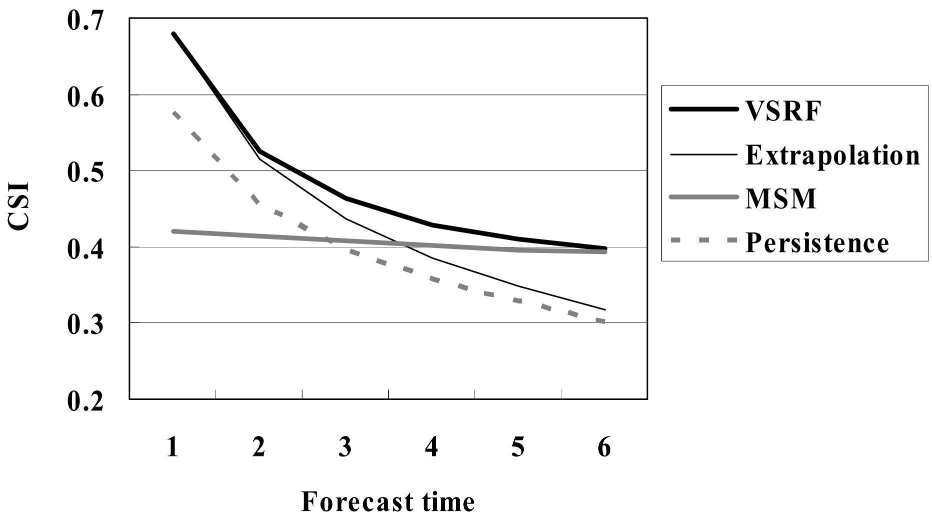


Figure 5.4.4 CSI of the very-short-range forecasting (VSRF) of precipitation averaged within the 20km x 20km grids for October 2006, together with that of the extrapolation, MSM, and the persistence forecast. Threshold value is 1mm/hr.

<u>Reference</u>


Makihara, Y., 2000: Algorithms for precipitation nowcasting focused on detailed analysis using radar and raingauge data, *Technical Report of Meteorological Research Institute*, **39**, 63–111.