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Research Article

Quality check of rain gauge data for quantitative precipitation estimate

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Abstract: The Quantitative Precipitation Estimation (QPE) method of the Japan Meteorological Agency (JMA) using radar and rain gauge data has been started to be deployed at the Viet Nam Meteorological and Hydrological Administration (VNMHA) since 2019 through a technical cooperation project of the Japan International Cooperation Agency (JICA). Quality control of radar and rain gauge data is a vital issue in keeping the accuracy of QPE. Especially rain gauge data is essential because QPE processes regard rain gauge data as exact values in calibration processes. VNMHA had yet to develop a quality control system and regular maintenance scheme for Automatic Weather Stations (AWS) and Automatic Rain Gauges (ARG). In order to make a reliable QPE product, a quality check for rain gauge data comparing mutual rain gauge data experimented and 1) missing data ratio, 2) proportion to mean of nearly ten stations, and 3) double sum curve check was selected as thresholds to select relatively reliable rain gauge stations. As a result of the quality check for rain gauge data in May 2023, 1,299 stations were chosen, and QPE with rain gauges selected showed stable precipitation distribution.

Keywords: QPE; Quality check; Rain gauge; Precipitation map; Radar data calibration.

1. Introduction

The bilateral cooperation project between the JICA and the VNMHA named "Strengthening Capacity in Weather Forecasting and Flood Early Warning System" has been conducted since June 2018. The project targets developing weather products for Disaster Risk Reduction [1]. As an indicator for precipitation monitoring, QPE was introduced during the 1st period of the project. QPE regards rain gauge data as teacher signals (exact values), calibrates radar observation data with it, and converts it to precipitation amount by using a simple Z-R relationship [2].

The algorism of QPE are: 1) quality control and one-hour accumulation of rain gauge data; 2) conversion from radar volume scan intensity data to lowest level distribution and one-hour accumulation; 3) 1st calibration by rain gauge data (comparison of precipitation at each radar area using converted precipitation from radar scans and rain gauge data); 4) 2nd calibration by rain gauge data (variational calculus methods, harmonizing both converted radar precipitation data in overlap area); 5) produce a national composite map [2–4].

VNMHA manages ten radars and around 2,000 AWS and ARG (hereafter described as "ARG"), and rain gauge data is collected to the Central Data Hub (CDH). VNMHA additionally manages 186 synoptic stations, and equipment at synoptic stations is compared with standard equipment regularly [4]. Synoptic station data is the most reliable data in Viet Nam; however, synoptic observation is implemented three- or six-hourly, and QPE requires at least one hourly precipitation data for its calibration processes. VNMHA calibrates/checks the accuracy of rain gauges at ARG before installing them; however, after installations, the accuracy of ARG is not checked frequently [5].

Ideally, the rain gauge of ARG should be quality checked with re-analysis data of Numerical Weather Prediction, for example, the WIGOS Data Quality Monitoring System (WDQMS) web tool [6], and equipment at doubtful observation should be checked and repaired promptly. However, VNMHA had yet to introduce a quality check system and maintenance on ARG stations. In order to evaluate the reliability of ARG data, the Radar Product Team (working group 2) conducted a quality check of rain gauge data for QPE in 2021 and 2022.

2. Indexes for quality check

For the operation of QPE, a collection of stable and steady rain gauge data is required, and VNMHA has a relatively dense observation network compared to nearby countries. In the quality check process, each station's data was compared with a mean of the nearest ten station's data (hereafter described as "area precipitation"), and the following indexes for the quality check were calculated.

1. Reporting ratio of ARG (more than 80 percent);
2. Reporting ratio of missing value and abnormal data (0-byte data) (less than 20 percent);
3. Abnormal data ratio (negative value or immense value, more than 500 mm/hour);
4. Small value data ratio 1 (no precipitation at the station when area precipitation is more than 5mm/hour);
5. Small value data ratio 2 (precipitation at the station is smaller than 1/10 of area precipitation);
6. Big value data ratio 1 (precipitation at the station is three times bigger than area precipitation when area precipitation is more than 5mm/hour);
7. Big value data ratio 2 (precipitation at the station is more than 15 mm, and area precipitation is smaller than 5mm/hour);
8. Proportion compared to area precipitation.

The trial was done for October 2021 data, and index-1 and index-8 were selected as thresholds. After excluding stations trapped by two thresholds, 3rd check was implemented by a double sum curve. A double sum curve (Figure 1) consisted of a time sequence of accumulated precipitation ($=\sum_{h=1}^{24\times[number\ of\ day\ in\ a\ month]}(R_h)$) at the station, nearest three stations and mean of area precipitation in a month in an upper figure and accumulated precipitation at nearest three stations and area precipitation (vertical axis) were plotted in a lower figure with accumulated precipitation at the exact station (horizontal axis). A good example is shown in Figure 1, lines smoothly changed in the same manner in an upper figure, and the angle of the plotted line was near the 45-degree line (y = x) in a lower figure.

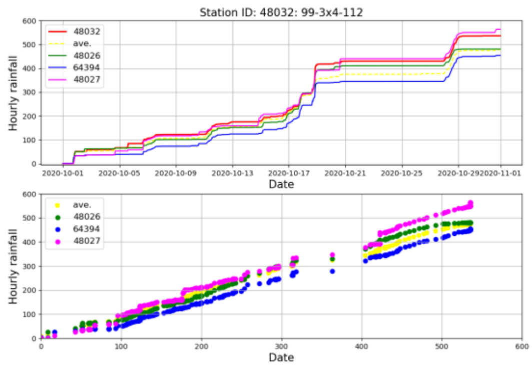

Figure 1. Double sum curve.

Examples excluded by the “double sum curve” are shown in Figure 2. In the case of a), in the 2nd half of the month, the lowest line (accumulated precipitation marked with ☆) did not increase because of failures on a rain gauge or a communication line. In the case of b), the shape of the curve on the lowest line (marked with ☆) is similar to others, but total precipitation is almost 40 percent of others. In the case of c), there were two gaps (surrounded by □) in an upper figure, and a few steps appeared in a lower figure.

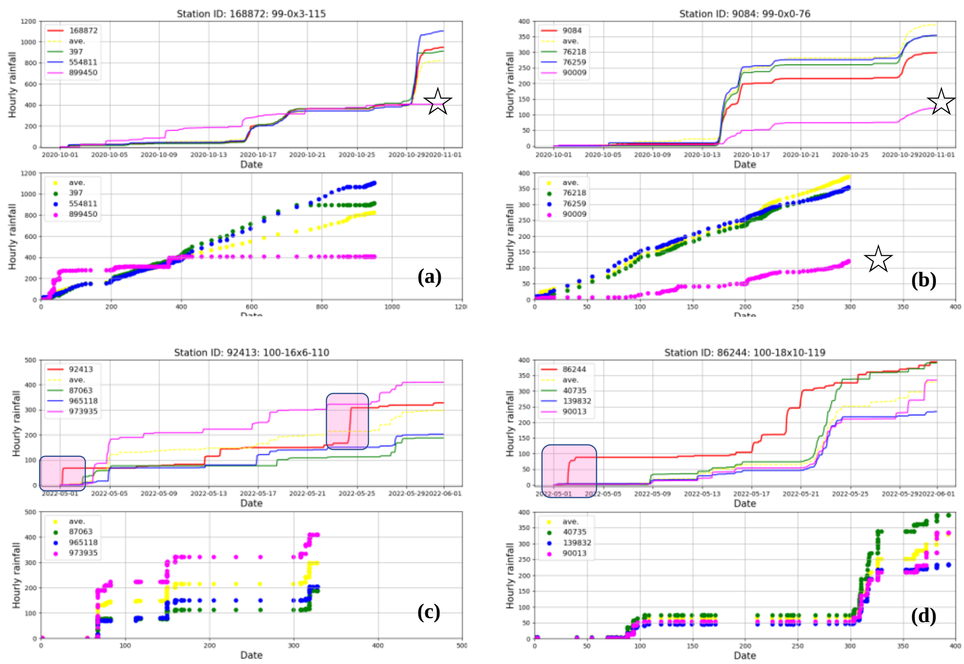

Figure 2. Double sum curves at stations excluded.

Observation failure seemed to happen at the station or isolated rain only nearby the station, or observation time was incorrect. In the case of showers brought by convective clouds, such isolated rains might happen; however, if such gaps are frequently observed, the data seems not to be reliable. In the dry season, the frequency and total amount of precipitation become smaller, and double sum curves tend to be scattered. Quality checks by double sum curves should be adopted for rainy season data.

The same evaluation was adopted for May 2022 data, and the review of ARGs is plotted in Figure 3. (Screening threshold was the same as in October 2021). In Figure 3, stations are categorized into three levels (Level 3: precipitation at the station is within 20 percent of area precipitation, Level 2: within 50%, and Level 3: within 100% of area precipitation). Level 3 stations (83 to 120 percent precipitation compared to area precipitation) are plotted as a circle (●), Level 2 stations (75-83 percent or

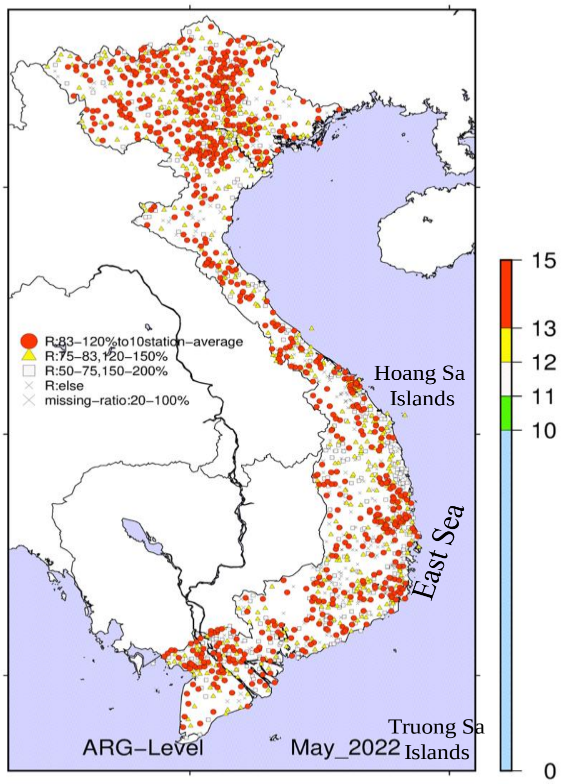

Figure 3. Evaluation of ARG.

150-200 percent to area precipitation) are plotted as a triangle (△), Level 1 stations (50-75 percent or 150-200 percent) are plotted as a square (□). Additionally, stations bigger than 200 percent or smaller than 50 percent value to area precipitation are plotted as a smaller cross (x), and stations with a missing report ratio of more than 20 percent are plotted as a bigger cross (✕). The number of ARG stations in May 2022 was 1,913; Level 3 stations were 774; Level 2 stations were 525 (Level 2+3 were 1,299), and Level 1 stations were 408 (Level 1+2+3 were 1,607).

As shown in Figure 3, the density of ARG is thicker in northern Viet Nam, and in these areas, the number of Level 3 stations is more; on the other hand, in a mountainous area, northwest area, coarse ARG area, for example, North-central area or in central, the number of Level 3 stations are smaller. As mentioned above, QPE treats rain gauge data as exact signals for calibration, so if VNMHA has a plan for new installation of AWS/ARG or quality check activities (AQC, maintenance activities at ARG stations), VNMHA could start activities from these mountainous areas or coarse ARG area.

3. Comparison of QPE results with the synoptic station

To evaluate QPE results, comparisons between 6 hourly precipitation at synoptic stations and QPE values at the nearest grid point were implemented. Monthly accumulated precipitation of QPE (1 hourly × 24 hours/day × 31 days) is plotted in the right figure, and monthly total precipitation at synoptic stations is plotted in the left figure of Figure 4. The QPE monthly precipitation map well-described distribution of spacial precipitation features in the month. In remote areas from radar sites, for example, northwest mountain areas, QPE precipitation tends to become smaller than synoptic observation data because radar cannot scan lower dense rain layers, radar locates far from areas, and/or geographical barriers block lower radar beams.

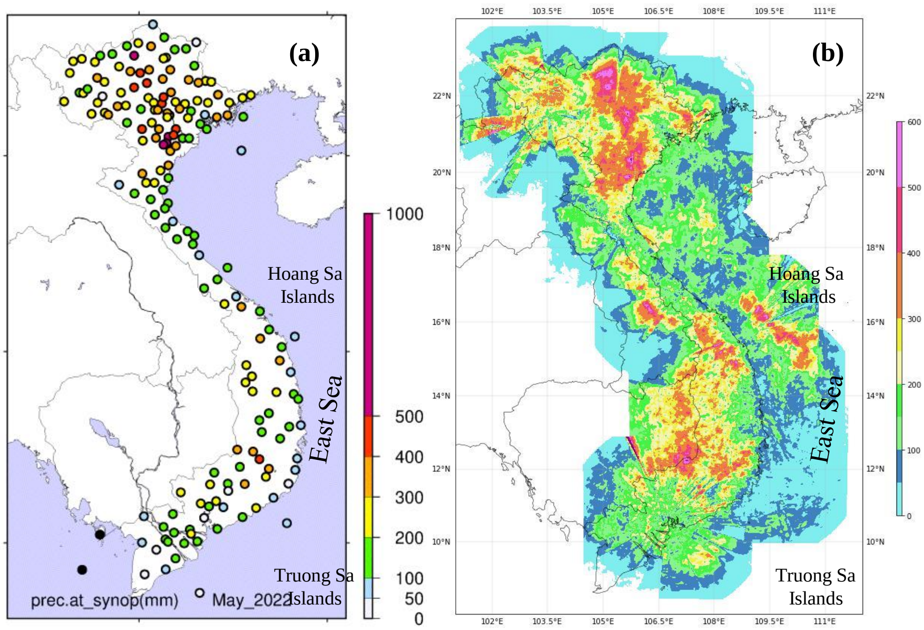

Figure 4. Precipitation at synoptic stations (a) and QPE (b).

Generally, the number of rain gauge data used for QPE becomes bigger, and the results of QPE become more stable. However, when big or small values were observed, especially in 2 radar-overlapped areas, sometimes over-calibration occurred, and then QPE results became unstable. An example of over-correction is shown in the upper figure of Figure 5. In this case, heavy rain was observed in 2 radar overlapped areas, and 2nd calibration factor became pretty big, and as a result, extreme rain areas were analyzed (surrounded by boxes). In the below figure of Figure 5, the results with ARG station table quality checked are shown. At 22UTC, there is a heavy precipitation area in the northern area, and at 24UTC, another strong rain area was estimated in the Lao PDR area (Figure 5). However, after removing abnormal data at 22UTC and 24UTC, QPE was adjusted and became more stable. In operational QPE, limitations of 1st and 2nd calibration factors are set to avoid over-correction caused by coarse rain gauge density in the overlap area in QPE processes, additionally.

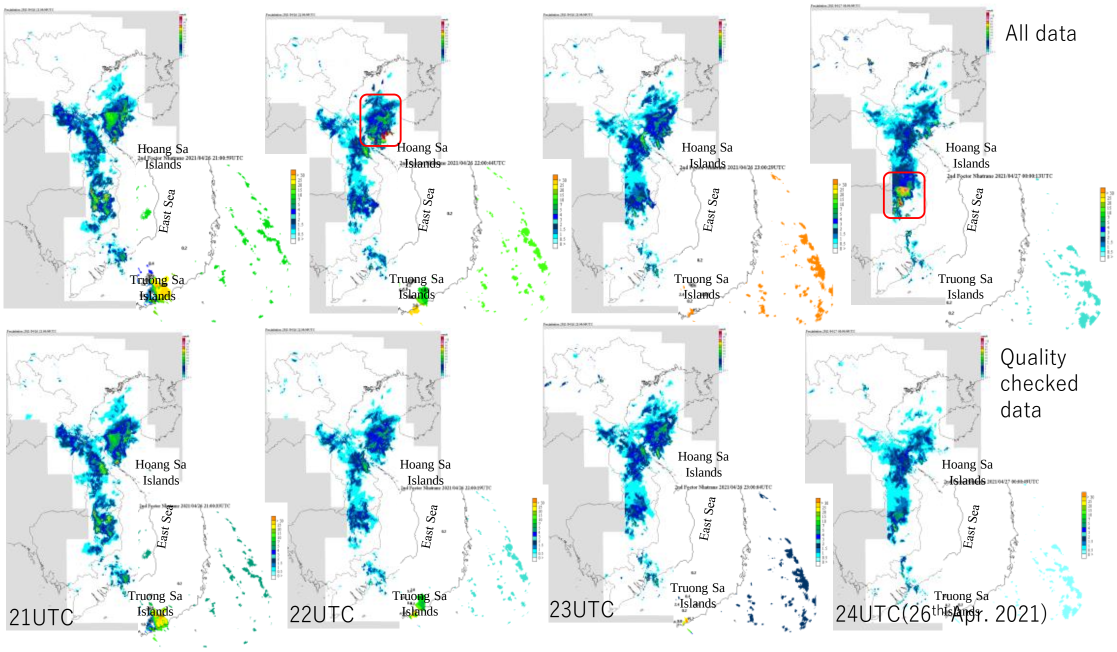

Figure 5. QPE results with quality checked data: upper: All data, lower: quality checked data, at 21 to 24UTC 26 April 2021, each figure shows QPE result and 2nd calibration factor.

Figure 6 and Table 1, comparison results between synoptic observation data and QPE 6 hourly accumulated data were shown. Comparisons were evaluated by the "slope" and "correlation coefficient" of simple regression equations. "Slope" is calculated as the slope in the regression analysis when the intercept is set as 0.0. The left figure is the correlation coefficient distribution, the middle figure is a slope of a simple regression equation (QPE precipitation to synoptic observation), and the right figure is the monthly total precipitation in May 2021 (accumulated 1-month precipitation by QPE).

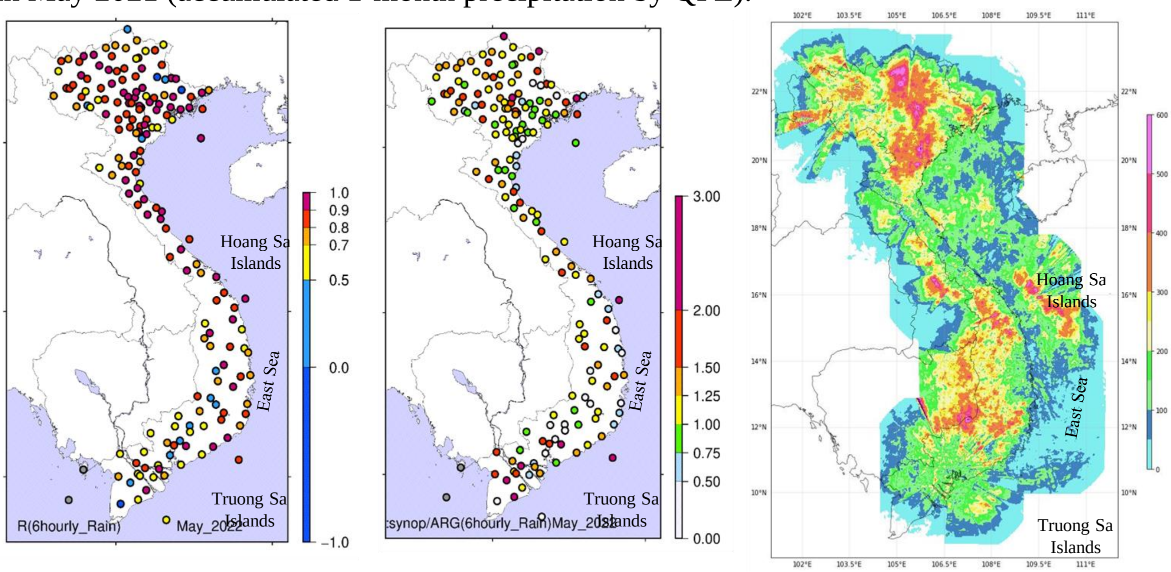

Figure 6. Evaluation of QPE with synoptic observation data (May 2021).

In the northern and north-central areas, the “correlation coefficient” is higher, but it is relatively small in the southern region. And “slope” of each station is mostly smaller than 1.0. It means QPE at the station is generally smaller than synoptic observation data. In mountainous areas or remote areas, the slope is bigger than 3.0 or smaller than 0.5. Stations with relatively smaller correlation coefficients and/or bigger/smaller slope factors should be checked first by comparison with a rain gauge checker through on-site maintenance activities.

If the number of stations becomes smaller, QPE becomes unstable, mainly when pretty heavy rain is observed. On the other hand, if the number of stations becomes bigger, risks which include not reliable stations, become bigger. Considering both demerits, the Level 2 station is recommended for QPE as a result of quality checks.

Table 1. Number of stations in evaluations of QPE and synoptic data in accordance with ARG-Levels.

	Correlation coefficient	Number of station	Slope	Number of station
Level 2	$0.9 \le$	50	0.83~1.20	57
~1,300	$0.8 \le$	104	0.63~1.50	113
	$0.5 \le$	165	0.50~2.00	151
Station table in October 2020	$0.9 \le$	42	0.83~1.20	52
~800	$0.8 \le$	92	0.63~1.50	102
	$0.5 \le$	162	0.50~2.00	142
Level 1+ 2+3	$0.9 \le$	50	0.83~1.20	55
~1,700	$0.8 \le$	107	0.63~1.50	114
	$0.5 \le$	165	0.50~2.00	151

(*) The total number of synoptic stations used for comparisons is 165.

Quality check processes for ARGs are summarized in Figure 7, and these comparisons were automatically implemented in the QPE server on a monthly basis. For stable QPE, quality checks on ARGs should be continued, and an ARG station list for QPE should be regularly updated based on Quality checks.

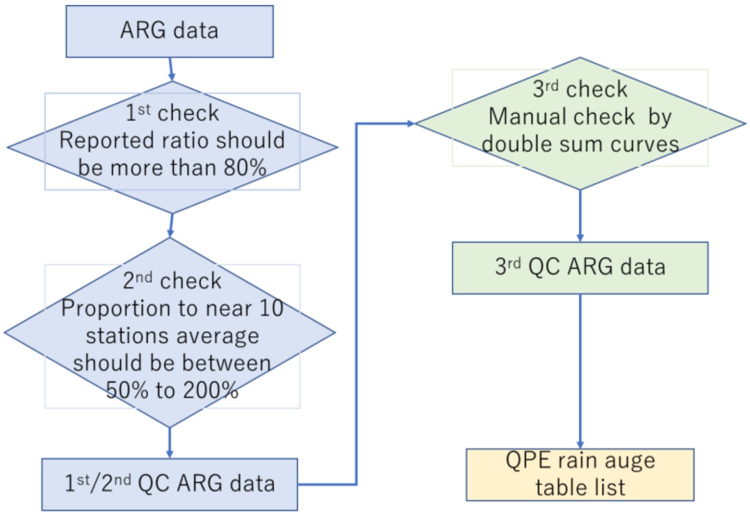

Figure 7. A flow for quality check of rain gauge for QPE.

3. Conclusions

The study results are: 1) a method for evaluating ARG data not considering other data (synoptic stations data) was reported; 2) QPE reliability was evaluated with synoptic data. To keep the accuracy of ARG observation, automatic quality checks and maintenance at ARG stations based on a guideline on maintenance are recommended.

In Japan, QPE data is used for soil water index, risk index for landslides, and flood risk index for flood (https://www.jma.go.jp/bosai/en_risk). And VNMHA operates QPE and shares its results on the website (http://amo.gov.vn/rain/) as 1-, 3-, 6-, 12-, 24-, 48-, and 72-hours accumulated precipitation maps. To develop risk indexes used in Japan, VNMHA needs to collect disaster events records with date, time, and location (latitude and longitude) to analyze with QPE data.

A table of rain gauge stations (Level 2) for QPE was proposed and temporarily used for its operation. For future research and developments of products, VNMHA needs to re-analyze QPE with quality-checked radar and ARG data. Raw observation data is indispensable for these purposes, and storage of raw observation data is strongly recommended.

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