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Research Article

Achievement of JICA technical cooperation project in period 2

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Abstract: Japan International Cooperation Agency (JICA) and the Viet Nam Meteorological and Hydrological Administration (VNMHA) have implemented a technical cooperation project entitled "Project for Strengthening Capacity in Weather Forecasting and Flood Early Warning System" for more than 5 years from May 2018. In period 2 from April 2020 to the present, the project has achieved some outstanding achievements. Automatic Weather Station (AWS) inspection and calibration method was trained by using the procured traveling standards for temperature, humidity, pressure and precipitation at headquarters, Phu Lien and Vinh. An operational tentative quality control system was introduced to check temperature and precipitation data in near-real time. Quantitative precipitation estimation (QPE) product has been operationally calculated by combining radar and selected rain gauge data. Methods to distinguish qualified rain-gauge data from poor-qualified rain-gauge data were introduced. Precipitation guidance was developed and tested in several heavy rain cases. Short-range precipitation forecasting up to 15 hours has been developed by combining the kinematic extrapolation method and mesoscale numerical forecast. Webpage and mobile application were developed to monitor rainfall situations and related warnings.

Keywords: JICA; Disaster risk reduction; International cooperation; Meteorological observation; Meteorological Forecasting.

1. Introduction

In Vietnam, heavy rainfall brought by typhoons and monsoons causes major disasters such as floods, inundations and landslides every year. To mitigate the damage caused by these disasters, it is necessary to improve the observation, analysis, and forecasting performance of heavy rainfall, as well as to improve the way information on heavy rainfall is presented.

JICA and VNMHA have implemented a technical cooperation project entitled "Project for Strengthening Capacity in Weather Forecasting and Flood Early Warning System" to achieve these objectives. The project was initiated in May 2018 and was originally planned to last until December 2021, but due to the COVID-19 issues that occurred during this period, the project was extended for two years and will continue until December 2023. Figure 1 shows the project implementation timeline. The overall project is largely divided into a first and second period, and the results of the first period, from May 2018 to March 2020, are summarized in [1]. This paper focuses on the results of the second period after April 2020.

Under this project, more accurate weather information will be provided to disaster management agencies and the public by improving (1) maintenance and traceability of meteorological observation equipment, (2) analysis and quality control ability for radar, (3) forecast/warning ability in heavy rain and typhoon, and (4) dissemination ability of meteorological information. The purpose of this project is to contribute to the utilization of the meteorological information provided by VNMHA for disaster risk reduction activities by disaster management agencies and the public. For this purpose, four outputs have been established, (1) maintenance of ground-based observation equipment including rain gauge and radar, (2) development of radar data analysis methods and QPE, (3) advancement of weather forecasting by utilizing observational data and results from numerical weather prediction model, and (4) communication and utilization of weather information. Figure 2 shows the overall project and the relationship among these four outputs. The four outputs are closely related to each other. Technical Working Groups are organized for each output and Working Group (WG) members, several officers from VNMHA and JICA experts, are assigned to implement each of the activities.

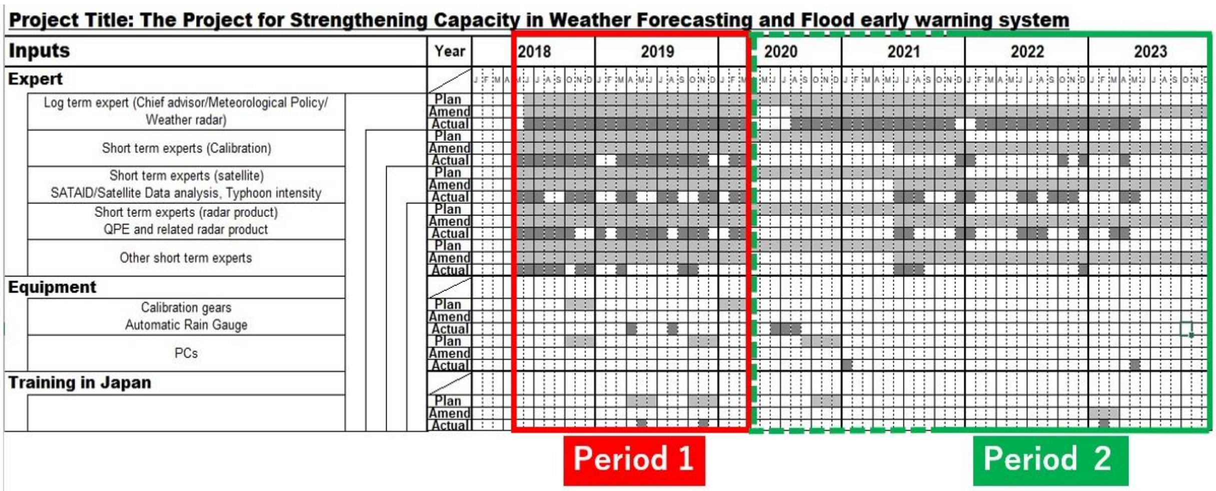

Figure 1. Project operation chart.

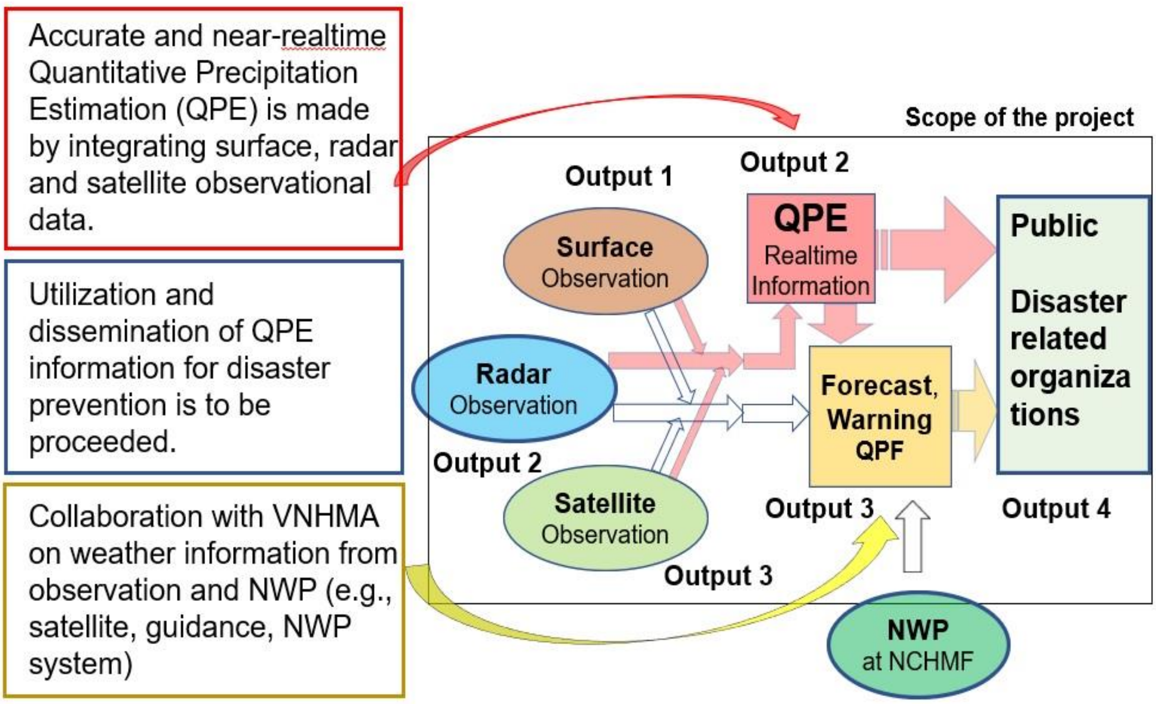

Figure 2. Structure of the project.

The results of the first period of the project are summarized as follows:

(1) Observations are conducted at Synoptic manned stations using common equipment, and the equipment is calibrated regularly. On the other hand, different AWS systems are installed by various providers, and calibration is performed only at the time of installation. Since AWS data will become more important in the future, it is necessary to establish a calibration system for AWS instruments. In addition, quality control of observation data needs to be introduced. Daily inspections of the radar are conducted by site staff and annual inspections are conducted by AMO technical staff, and the equipment is operating stably. Several improvements in radar settings, such as scanning sequences, are future issues.

(2) JMA QC/QPE package was introduced, and a system was built on a trial basis to be applied to 10 radar data and AWS data of about 800 sites. After several improvements in the setting to calculate QPE, this system stably produced QPE products. The selection method to distinguish good-quality rain gauges data from poor-quality rain gauges data should be improved.

(3) Guidance on forecasting maximum and minimum temperatures in 63 cities was developed, and better results were obtained than the numerical weather prediction (NWP) model output itself. In addition, training was conducted on how to analyze numerical forecasts, radar, and satellite data in heavy rainfall cases and how to use them in forecasting work.

(4) Expert surveyed the actual utilization of meteorological information which VNMHA issued. In addition, basement construction work for the installation of new ARGs at 18 sites was conducted to improve the accuracy of QPE, and the installation of ARGs was completed for 15 sites. Real-time data monitoring also started at headquarters.

For details on these activities, please refer to [1].

2. Summary of Activities in Period 2

As mentioned earlier, activities in period 2 stagnated for more than 1 year due to COVID-19. During the COVID-19 restrictions, some lectures and seminars were held online or a combination of online and offline. Activities were resumed as the situation became better. For each output, the results of the second period are summarized as follows.

2.1. Output 1 (observation)

To improve the calibration capability, a thermostatic chamber for temperature calibration was provided to the calibration laboratory in Hanoi, and four sets of mobile standards for atmospheric pressure, temperature, humidity and rainfall were also provided. On the job-training (OJT) was conducted in December 2021 and January 2022 at the headquarters, and in October 2022 at Vinh and Phu Lien regional centers on how to check AWS using these mobile standards. The need to conduct these checks systematically in the future was strongly recommended. In addition, a draft maintenance check sheet was prepared for uniform management and accuracy maintenance of AWS instruments and was tested during the OJT.

The training was given on the importance of metadata, which is the basis of observatory management, and location information was checked for several sites, and it was pointed out that the information currently registered was incorrect. It is also important to record calibration records and differences from standards in metadata as part of instrument management.

To clarify the current situation of rain gauge observation, quality analysis of AWS rain gauge observation was made by comparing with Synoptic observation. The results are given in [2]. A training course by the Japan Meteorological Agency (JMA) lecturers was held in December 2022 to improve the quality control capability of surface observation.

2.2. Output 2 (radar analysis)

A characterization survey of AWS rainfall data at about 1,800 locations is available and classified into levels in terms of reliability. Two-dimensional checks and double-mass analysis were used to check the quality of each AWS data. QPEs using AWS at each level were compared to determine the appropriate level of AWS for use. The results of this analysis are given in [3].

To mitigate the abnormal fluctuations in QPE values that occurred at the beginning of the QPE operation, optimization of the configuration parameters within the QPE algorithm was conducted. As a result of this adjustment, the QPE calculation stabilized and can be used for heavy rainfall monitoring. To further enhance its use for heavy rainfall monitoring, products superimposed with satellite data in SATAID software can also be used.

To improve the accuracy of QPE, training was conducted on how to create clutter maps to deal with ground clutter echoes that can't be removed by the signal processing system, and clutter maps can be introduced in the operational system.

After implementing these various improvements, the calculated QPE was compared with the rain gauge for evaluation, and the characteristics of the QPE were analyzed. As a result, whole accuracy was improved with some low accuracies in areas such as mountainous areas, southern areas, and areas with sparse rain gauge distribution areas.

To improve the accuracy of QPE, the introduction of dual-polarization data was discussed. Quality checks of original data and correction are necessary for the utilization of dual-polarization data. In addition, to make better use of QPE data for disaster prevention, some trials for the superposition of accumulated QPE data with different time intervals and disaster risk maps were made, to specify the estimated area for disaster occurrence.

2.3. Output 3 (forecast)

Improvement of temperature guidance was implemented. The accuracy of guidance was improved by combining the results of multiple NWPs, compared with the result of a single NWP. The guidance that extended the forecast period from 3 to 9 days was also created, and a new PC was prepared in which these products can be monitored in near-real time.

To create precipitation guidance, several cases of heavy rainfall were analyzed and a dataset for creating guidance was developed. Statistical analysis using the dataset was conducted and a prototype guidance based on GSM and IFS results was developed and tested. The results are given in [4].

To improve short-term disaster prevention information, a prototype system of the very short-range forecast of precipitation in Vietnam was developed by merging kinematic extrapolations of composite hourly rainfall analysis and NWP. Verifications showed that the merged rainfalls outperformed both NWP and kinematically extrapolated precipitations for the time range of Forecasting Time (FT) = 3 to 5. Detailed results are described in [5]. To improve short-range NWP, JMA's strategies, including radar data in NWP were introduced in seminars and lectures in training courses [6].

2.4. Output 4 (dissemination)

Three ARGs were installed in mountainous areas and remote island. Together with the 15 ARGs in the first period, we set up 18 ARGs as rain gauge systems for data collection and monitoring and conducted training on how to maintain and manage these systems including the method how to change system settings. In addition, at the 18 ARG installation sites, training was conducted on the maintenance of observation equipment and accuracy confirmation.

Mobile applications and websites for monitoring ARG, radar, and satellite data were developed and put into operation. In addition, weather and disaster prevention information was also made available for monitoring in the application or website. A detailed explanation for these developments is given in [7].

2.5. Others (training and seminars)

During the project period, a lot of training sessions and seminars related to each of the outputs were held. OJT training was provided at the actual sites for the maintenance and calibration of surface instruments and radar systems. In addition, we invited experts from JMA to conduct training with participants from not only headquarters but regional or local meteorological observatories. We also held training in Japan in which not only lectures or exercises but also site visits to JMA or related organizations were implemented as activities of outputs 1, 2 and 3. A detailed list of these training and seminars is compiled in a separate technical report [6].

3. Additional information on ongoing activities

The project is still ongoing, and some additional information on ongoing activities that are not fully described in section 2 is provided below.

3.1. Near-real time quality control of surface observation data

Since surface observation data are being archived in the Central Data Hub (CDH) in near-real time, we created a tool to read out the data from CDH, perform simple quality control, and display the results. Currently, the target is temperature and rainfall observation data. Each regional center/ local observatory can easily check the condition of instruments within their responsible areas. Figure 3 shows an example of the display. Blue points show normal condition, black points show no data in CDH, and red point shows some possibilities of a problem at the site. You can click this red point and the time variation of the observation data can be displayed in terms of graphic charts, so it is possible to estimate the cause of the problem. In this case, an abrupt change of more than 150 mm in 1 hour is one of the criteria to check the validity of rainfall data.

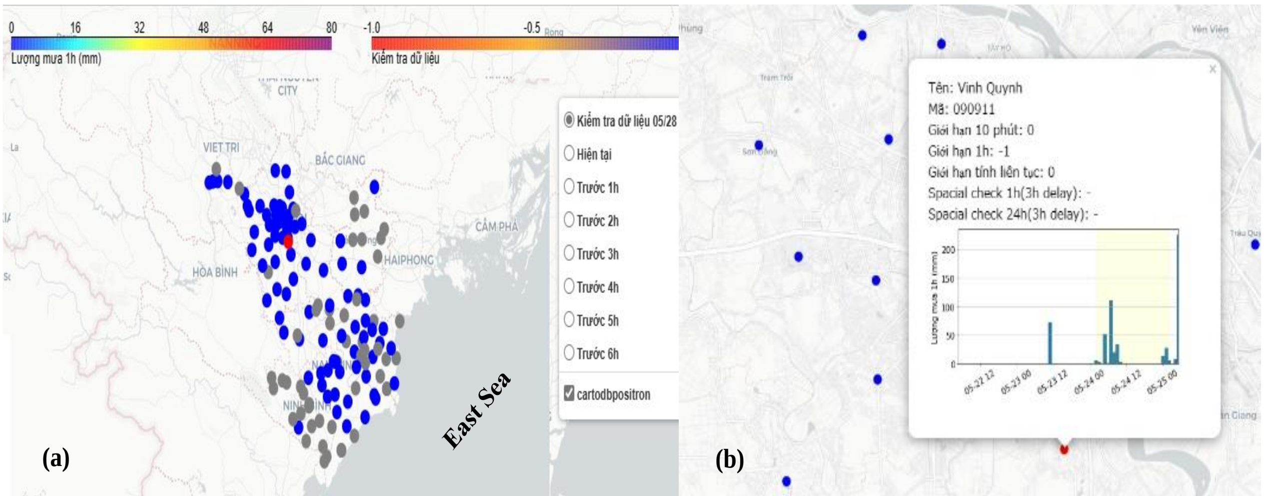

Figure 3. (a) Sample status display of rainfall observation in the Northern Delta region. Blue points show normal, black points show no data and red point shows the possibility of a problem. (b) After magnifying the left display and show the time change of rainfall amount at the red point to check the cause of the problem. (Courtesy of R. Kobayashi - an expert in Output 1).

This display system should be monitored periodically, and on-site investigations and inspections should be conducted for observation points where problems frequently occur.

3.2. Introduction of a disdrometer

Two disdrometers, which can measure the rainfall size distribution on the ground, were installed in December 2022. Currently, a test observation is being conducted in Hanoi with one installed on the roof of the headquarters and the other in the observation field of Ha Dong station. Figure 4 shows the one installed at Ha Dong station.

The observed rainfall size distribution can be used not only to know the characteristics of rainfall in Vietnam but also to calibrate the radar data. Radar reflectivity is highly dependent on rainfall size distribution, the relation between rainfall amount and radar reflectivity can be estimated by using observed rainfall size distribution.

Figure 4. Disdrometer installed at Ha Dong station.

3.3. Utilization of dual polarization data

VNMHA currently operates five dual-polarization radars. By utilizing dual-polarization data, it is possible to analyze rainfall amounts with higher accuracy than with single-polarization radar. Several methods for calculating precipitation from dual-polarization data have been proposed for several different regions. In the future, it will be necessary to determine the optimal method for calculating precipitation in Vietnam by combining the disdrometer data described in 3.2 with dual-polarization observation data.

In addition, since dual-polarization radar analysis depends on subtle differences between horizontally and vertically polarized observations, it is necessary to calibrate radar observations more carefully than single-polarization radar. For this reason, it is necessary to check the dual-polarization data carefully on a daily basis to confirm that the characteristics of the radar have not changed.

4. Future activities and suggestions

This project has made it possible to derive hourly precipitation distribution (QPE) with 1km mesh in near-real time and to conduct quantitative analysis of heavy rainfall that could lead to the estimation of the occurrence of several disasters. In the future, it is necessary to further improve the accuracy. To improve the accuracy of the product, the following points need to be considered. The first point is to improve the accuracy of rain gauge and radar data, which are the basis of the product. To utilize more accurate rainfall data from approximately 2,000 AWS sites nationwide, it is necessary to improve quality control of observation data and develop maintenance management systems, such as calibration and overhaul of rain gauge. Quality control should not be used only to eliminate poor quality data, but should also be used to accelerate an inspection for poor quality stations and encourage calibration and repair of instruments. Regarding the accuracy of QPE, the rain gauges in some areas are so important such as mountainous areas where there are few observation points, areas where multiple radars overlap, area which is important for the QPE calculation algorithm. It is necessary to implement inspection and repair of rain gauges in such areas as a first priority.

For radars, it is necessary to review the scan sequence for optimal observations and to improve the elevation angle table used to calculate PCAPPI. Also, corrections for the radar beam shielding by using high-resolution terrain data will improve accuracy. In the case of dual-polarization radar, correction for rainfall attenuation can be useful and it is easy to utilize this product in the system.

The second point is the improvement of the product calculation algorithm. The current QPE algorithm does not use the beam height information of the observation data when handling PCAPPI data. The improvement of this point is expected to improve the calculated rainfall values. In addition, the current algorithm is based on the correction with rain gauges, if a rainfall area exists only over the ocean, the correction by rain gauges may not be effective and the correction may be insufficient. When using current QPE products, it is necessary to know the characteristics of such products.

There are two major directions in which QPE products can be applied. One is to calculate a disaster risk index which is more closely related to the disaster from the rainfall itself. Early warning information for the disaster is issued based on this kind of index. Landslides, floods, and inundations are three major disasters caused by heavy rainfall. These disasters are caused by a combination of several factors including soil moisture or total precipitation in the basin, in addition to the amount of precipitation at the disaster location. Therefore, it is necessary to calculate the soil moisture index, runoff index, and inundation index that are closely related to the occurrence of each disaster when these indexes are combined with rainfall amount. In addition, since the conditions for the occurrence of disasters vary from region to region, it is necessary to decide the criteria to estimate the occurrence for each region. To decide the criteria in each region, past records of rainfall and disaster in that region are necessary. By using these past records, the index can be calculated and compared the index with past disasters for each region and establish criteria such as which value of the index should prompt early warning of the occurrence of a disaster in that region. For this purpose, it is necessary to compile data on the occurrence of past disasters for each region, and such a database needs to be developed along with data on past rainfall amounts.

The second way to utilize QPE products is to use them for precipitation forecasting. For precipitation forecasting, there are two major methods depending on the forecast time. For forecast less than 1 hour, the kinematic extrapolation method is useful and forecast longer than 6 hours the utilization of numerical weather prediction is useful. For forecast times between 1 and 6 hours, it is effective to combine the results of both kinematic extrapolation and numerical weather prediction. QPE products are used as initial conditions for kinematic extrapolation. In the future, it will be important to utilize these methods according to the forecast time.

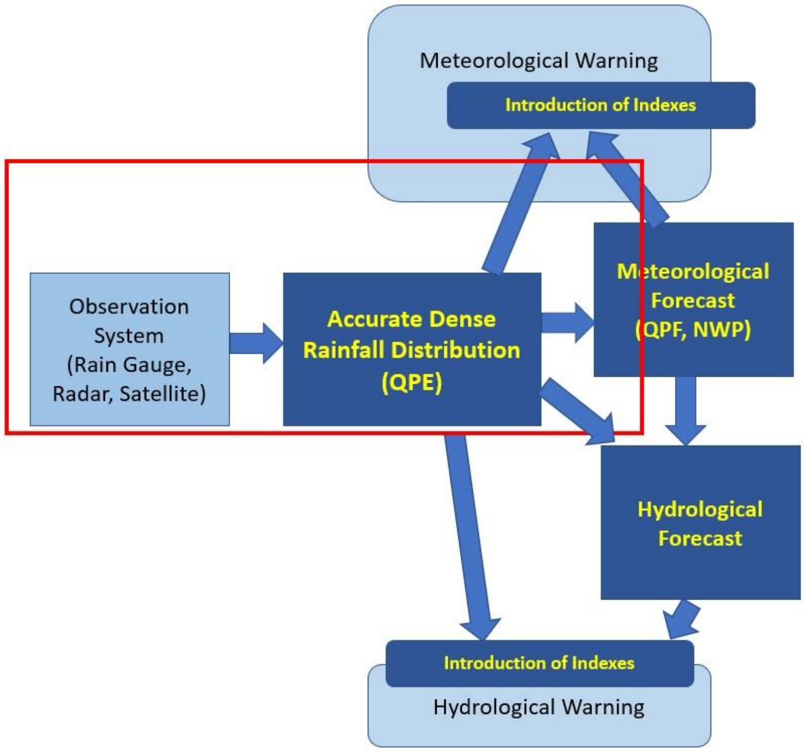

Figure 5. The schematic chart creates early warnings from observation through forecasting to final warnings. This technical cooperation project covers the field showing the red box.

While there are various methods to improve the accuracy of precipitation forecasting in NWP, it is also important to assimilate observed information on wind and water vapor into NWP. From meteorological radar, it is possible to set up a wet (100% humidity) area by considering the radar echo area as a cloud area and it is possible to assimilate wind information from Doppler data. In addition, it will be useful to introduce new observation systems for deriving wind and water vapor information and to assimilate these data into the NWP model.

Figure 5 shows a simple schematic diagram from observation to information dissemination for disaster risk reduction due to heavy rainfall. In this project, we have mainly conducted the part where precipitation distributions are created from observation data and partly conducted their utilization on the forecast and information dissemination. In the future, it is necessary to contribute to disaster risk reduction in Vietnam by enhancing the areas of meteorological and hydrological forecasting and developing indexes and regional criteria to improve the accuracy of warnings.

5. Conclusion

This project established a technical basis to derive QPE by combining rain gauges and radars. This product covers the whole area of Vietnam hourly with a resolution of 1km. There are several factors to keep its quality or improve its quality. Maintenance and calibration of observational systems, including rain gauges and radars, keep the accuracy of observation data and lead to achieving the quality of QPE. Some evaluation and adjustments of the settings of QPE algorithm are also necessary to improve its quality.

Temperature and precipitation guidelines were developed in this project, which showed better results than the model output. A prototype system of the very short-range forecast of precipitation was also developed by merging kinematic extrapolations of composite hourly rainfall analysis and NWP and QPE product will be used as initial state of the kinematic extrapolations. Further strategies of NWP development are necessary to improve the performance of short-range forecasting.

The project aims to disseminate weather information based on the developed product in this project. New risk maps are tentatively developed based on QPE and new mobile application and web pages are developed. Further development of information for disaster risk reduction based on new indexes is future issues. For developing more accurate and timely meteorological information, VNMHA and JICA continuously challenge to clear matters step by step steadily.

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References

1. Tonouchi, M.; Kasuya, Y.; Tanaka, Y.; Akatsu, K.; Akaeda, K.; Thu, N.V. Activities of JICA on disaster prevention and achievement of JICA project in Period 1. *VN J. Hydrometeorol.* **2020**, *5*, 1–12.

2. Kobayashi, R.; Duc, L.X.; Tien, P.M. Attempt to detect maintenance-need rain gauge station by double-mass analysis. *J. Hydro-Meteorol*. **2023**, *15*, 10–20.
3. Tonouchi, M.; Hoa, B.T.K.; Hung, N.V.; Cuong, N.M. Quality check of rain gauge data for Quantitative Precipitation Estimate. *J. Hydro-Meteorol*. **2023**, *15*, 21–27.
4. Sasaki, K.; Anh, V.T. Development of precipitation guidance for 36 regions in Vietnam up to 5 days ahead. *J. Hydro-Meteorol*. **2023**, *15*, 40–58.
5. Saito, K.; Hung M.K.; Tien D.D. Development of a prototype system of the very short-range forecast of precipitation in Vietnam. *J. Hydro-Meteorol*. **2023**, *15*, 59–79.
6. Akaeda, K.; Saito, K.; Sasaki, K.; Ichijo, H. Training and seminars at the JICA project in Viet Nam. *J. Hydro-Meteorol*. **2023**, *15*, 91–105.
7. Ichijo, H.; Manh, N.V.; Phuong, V.M.; Huy, N.V.; Nhan, P.V.T. Development of Mobile Services for Weather Observation Information. *J. Hydro-Meteorol*. **2023**, *15*, 80–90.
8. JICA and JMBSC. The project for strengthening capacity in weather forecasting and flood early warning system in Vietnam. Progress Report 4 (Second period), 2023, pp. 75.