Implementation of Disaster Prevention-Oriented Information Service Platform of XRAIN on DIAS

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Abstract— In recent years the phenomenon of localized burst has increased in Japan. The disaster caused by local heavy rain is often serious, and disaster prevention measures have become urgent. X band MP Radar (called XRAIN) was Installed throughout Japan because of high spatial resolution, which was higher than that of conventional radar; the shortened observation time was useful for localized burst. However, the quantity of data of XRAIN are on a macroscale approximately 1,000 times bigger per day than conventional radar; thus, it was not easy to develop an environment that accumulated data in data-producing, and information sharing was difficult. Therefore, on DIAS, which is a earth environment data platform with the largest volume of storage in Japan, an information platform that acquired and accumulated and shared XRAIN data was developed for the purpose of information sharing. In this study, we addressed three problems in handling large-capacity data: 1. Processing delay; 2. Overlapped data; 3. Low presentation speed. We implemented solutions to these problems and develop a stable information platform on DIAS. As a result, DIAS contributes to the study of flood disaster prevention measures and is the most important information platform for XRAIN. In this paper, we introduce problems and methods are suggested for the solution; in addition, the implementation result that occurred in developing this information platform is reported.

Keywords-component; XRAIN; X band MP Radar; Big Data; Rainfall information; Visualization; Disaster prevention; Observation information; Parallelization; Overlapped data; Resolution conversion

I. Introduction

Because 70% of the land in Japan is mountainous, typhoons and heavy rain have a strong impact. Uniform rain is common in Japan, and there are few examples of extreme heavy rain except for typhoons. However, in recent years, changes have been observed in the rainfall. Weather conditions change suddenly, and there are many local phenomena, with occurrences of intense rain. Weather changes caused by localized bursts occur randomly. Therefore, prediction is difficult using only the rain information that has been collected thus far. Localized bursts cause floods, landslides, and mud floods. As a result of heavy rain around Kanto and Tohoku on September 9, 2015, the Kinugawa River levee collapsed, and large-scale damage affecting more than 20,000 people occurred, including the complete destruction houses as well as partial destruction and inundation; 8 people died, and 79 were injured. One year after the disaster, many victims continued to live in temporary housing provided by the government and the government. The cost of localized bursts increases every year. Disaster prevention measures, including prediction methods, are urgently required.

One of the most important aspects of anti-disaster measures is rain information. C-band radar [1] data are observations that captures rain of whole country widely; it is difficult to observe local rain in a narrow area, which has frequently occurred lately. Therefore, XRAIN has been introduced to observe local rain.

XRAIN is an observation network by X band MP (Multi-Parameter) Radar; Ministry of Land, Infrastructure, Transport and Tourism(MLIT) [2] manages 39 sites (as of December, 2016) in Japan. These radars have high spatial resolution that is 16 times higher than that of the C-band radar, and they are able to observe in short periods of time (1 minute); the data are extremely useful for the analysis and study of localized bursts. Therefore, sharing information of XRAIN is considered very important. However, the improved high spatial resolution and observation frequency increased the volume of data in comparison with C-band radar by approximately 1,000 times; it was therefore difficult to accumulate all these data in MLIT-related facilities and to disclose information. Therefore, DIAS [3], which is a platform for global environmental information with the largest volume of storage in Japan, developed a system that acquired and accumulated XRAIN data for the purpose of information sharing of XRAIN data from MLIT; in July, 2014, DIAS began use as the information platform of XRAIN.

The environment in which researchers and general users are able to share XRAIN data was developed on DIAS, and it began to be used in October, 2015. The system of information sharing prepares two products for general users and researchers, one allows general users to browse real-time XRAIN data, and the other allows researchers to browse and download more detailed data.

On DIAS, three problems occurred due to the volume of XRAIN data. The first is processing delay. Because the interval time that XRAIN data are transferred is extremely short, and because all acquisition, accumulation and processing of data must be completed in less than 1 minute, an improvement of the processing methods was necessary.

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The second is overlapped data. MLIT divides XRAIN data for operative management into 14 areas and does not handle it nationwide. The transfer to DIAS is also carried out in all of the 14 areas. Because this caused overlapped data, it was necessary to take measures to keep the integrity of the data. The third is the lower presentation speed. The browsing service for general users is available with smartphone for improvements in convenience. However, because of the large amount of XRAIN data, information presentation took time, and this solution became the problem.

In this study, we suggested solutions to the problems mentioned above and implemented them for the purpose of developing a stable and reliable information platform for disaster prevention measures, specifically flood disaster. This system started operation in April, 2016; DIAS is a leading information platform of XRAIN data which contributes to studies on disaster prevention measures for flood disaster in Japan.

The remainder of this paper is organized as follows. In Section II, we provide a summary of XRAIN. A processing outline for DIAS is presented in Section III. Suggestions for the methods that solved three problems in developing system, and implementation results are described in Section IV. Finally, we state our conclusions in Section V.

II. SUMMARY OF XRAIN

In this section, a characteristic of XRAIN is introduced in comparison with the C-band radar of conventional radar (Table 1).

TABLE I. COMPARISON BETWEEN C-BAND RADAR AND XRAIN

Radar	C-band	XRAIN
Observation interval	5 minutes	1 minute
Time required for transfer	10-15 minutes	1 minute
Spatial resolution	1km mesh	250m mesh
Frequency	4～8GHz	8～12GHz
Observation area	Radius 120km	Radius 60km
Transfer unit	nationwide area	local area
Data volume	98 KB / 5 minutes 28 MB/ per day	19295 KB/ 1minute 27785MB/ per day

C-band radar is a single polarized wave radar; rain strength is calculated by the strength of the electric wave that is reflected by a raindrop. Because the parameter necessary for this calculation varies according to the state of the rain, revision of the value using rain gauge above the ground is necessary. Therefore, extra transfer time is required.

XRAIN transmits and receives two kinds of polarized waves (horizontal and vertical) and determines the shape of the raindrop; it is also the observation radar for the multi-parameter method that estimates rain strength based on the configuration of the raindrop. This radar enables highly precise observation, and revision with a rain gauge above ground is not necessary. Therefore, it shortens the time required for observation and data distribution, and acquisition of observation information is rapid and almost in real-time.

The spatial resolution of XRAIN is a 250-m mesh, which is approximately 16 times higher than that of C-band radar with a 1-km mesh. Because the observation area of XRAIN is small, with a radius of 60 km, and within one minute of observation, XRAIN can capture a peak of rainfall; it is suitable for the observation of localized bursts. With C-band radar, it is difficult to capture a peak because the observation area has a radius of 120 km and the observation time is 5 minutes.

XRAIN has been installed in 39 locations (as of May, 2017) throughout Japan by MLIT. The radars are located in observation areas that are vulnerable to heavy rain, i.e., large cities, volcanos, disaster restoration locations, and in all government ordinance designated cities. For each radar, the angle of elevation setting in relation to the topography is determined elaborately in MLIT, and a stable value is established [4]. However, because XRAIN has a short wavelength (high frequency), as shown in Table 1, very heavy rain blocks the progress of the electric waves of the X-band zone, and electric waves are attenuated, making observation impossible. MLIT surrounds each observation area with plural X-band MP radar antennas; this reduces the risk of not being able to measure values by supplementing data acquisition. For examples, we show the position of the X-band MP radar antenna in the Kanto area, Japan in Fig.1.

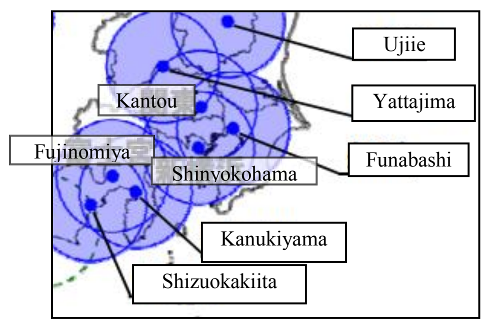

Fig. 1. Cover area of the X band MP radar antenna (at May, 2017) [5]

In MLIT, primary processing adapts observed values to real values. Then, synthetic rainfall is calculated from acquired values by plural antennas surrounding the spot concerned. Demand for the values of synthetic rainfall calculated in this way is highest for studies. The values used for sharing information in this study are the values of this synthetic rainfall.

MLIT manages the radars in 14 areas (as of May, 2017) by calculation of the synthetic rainfall occurring in each of the 14 areas (Fig. 2), but there is no link between the data. In other words, the values of the location concerned are not adjusted by data from different areas when they are different.

Because the radar often observes multiple areas, each local range becomes a factor in the data overlapping, as described later. Since C-band radar has distribution units to DIAS nationwide, these problems have not occurred.

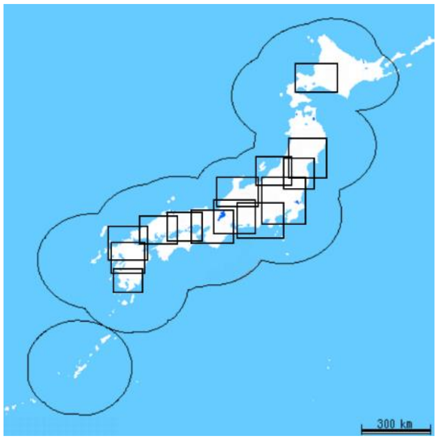

Fig. 2. Observation area of XRAIN [6]

III. OUTLINE OF XRAIN PROCESSING ON DIAS

In this section, outline of processing for acquisition of XRAIN data and information service platform for users on DIAS are introduced.

A. Acquisition and visualization

DIAS is an Integration and Analysis System developed and managed by EDITORIA [7], which is supported by MEXT [8]. DIAS has super large-capacity storages of about 25PB (as of December, 2016) and huge analysis spaces and many server clusters; it can carry out acquisition, accumulation, unification, and analysis of data mainly provided by global observation. Not only huge volume of data accumulation but also various data handling application and analysis tools are prepared on DIAS [9] [10].

DIAS accumulates all information about XRAIN data generated in MLIT. Specifically, the following 3 values are captures: 1. Values of observation information before processing (raw data); 2. Values after primary processing; 3. Values of synthetic rainfall. The data of XRAIN where observation and composition were carried out by MLIT are divided into 14 files and are transferred to DIAS every 1 minute.

DIAS performs visualization processing using synthetic rainfall immediately after the data are acquired from MLIT. Specifically, following image (Fig. 3) shows processing for visualization and processing that outputs a file in an easy-to-use form.

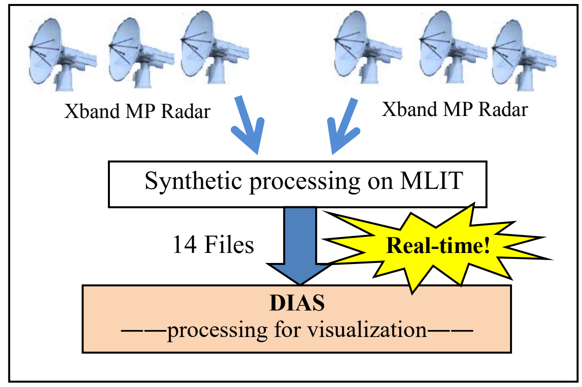

Fig. 3. Outline of acquisition XRAIN data processing on DIAS

Next, outline of visualization processing on DIAS is addressed.

First, the synthetic rainfall of all areas and the positional information (latitude and longitude) of the locale concerned are extracted from each area file (14 files). Then, they are presented by the two-dimensional sequence using the XY coordinate and are created as an image and assigned a color depending on the rain strength of the synthetic rainfall. These results are stored as a file of the area unit in chronological order. The abovementioned process is repeated for all 14 areas （Fig. 4）.

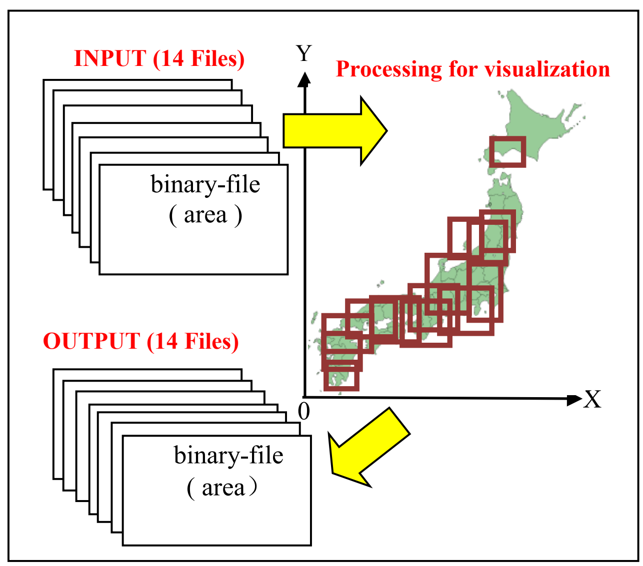

Fig. 4. Overview of the images making processing for visualization

B. Information service platform for XRAIN data

The information service platform for XRAIN data are developed as two products, one is for general users and the others is for researchers, and the images implemented in the previous subsection are used for browsing on each product.

In terms of the information browsing feature for general users "AMeNOW!" [11] (Fig. 5), abovementioned images and images which are created as measures for a performance problem described in the later section are used. The users can browse localized burst information (still images and animations) with a PC or a smartphone in real time. In addition, users can also browse the information retroactively.

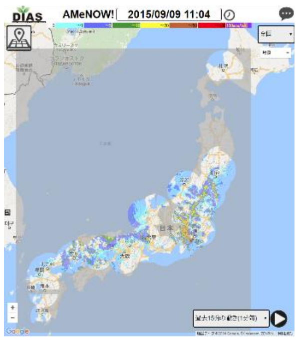

Fig. 5. Browsing screen for general users

On information service platform for researchers on DIAS, functions that can download all accumulating XRAIN data and can browse more detailed information are developed.

Images made by visualization processing are used by the browsing feature. When an area (or whole of country) and a target day are chosen on a designated screen, all the still images of that date are displayed in thumbnail form. (Fig. 6) When an image is chosen here, an image is enlarged and can browse it (Fig. 7). In addition, users can browse a still image on a map (Fig. 8) and animation. Users can also browse all images for the past as well as real-time observation information.

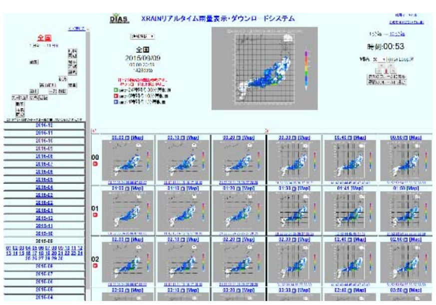

Fig. 6. Browsing screen for researchers

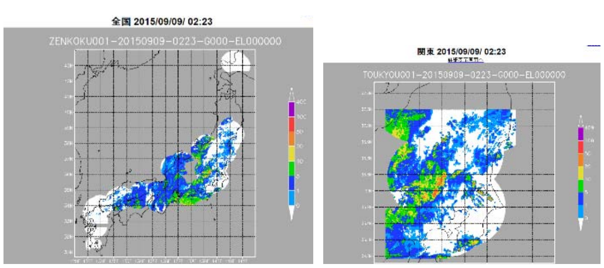

Fig. 7. Enlarged image of the XRAIN observation information

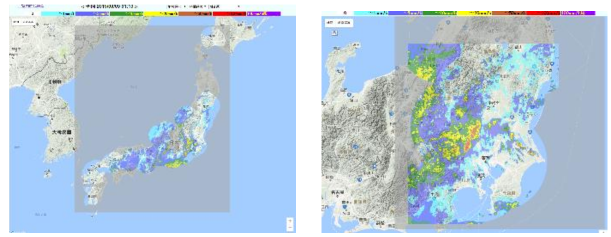

Fig. 8. The XRAIN observation information displayed on a map

Users can download XRAIN data including the positional information of a chosen area by choosing the necessary area on an image displayed on a map (Fig. 8). The data that users download here are the output data of the synthetic rainfall abovementioned. In addition, users can download raw data as well as data after primary processing; as a result, can download the data of all XRAIN data accumulated in DIAS.

IV. Implementation of the Disaster Prevention-Oriented Information Service Platform of XRAIN

The XRAIN data are extremely useful as disaster prevention measures of the flood disaster caused by localized burst, and the value of information sharing is high. However, XRAIN observation information is one of the largest sources of real-time data that DIAS handles, and the transfer interval is very short. Therefore, in this study, many solutions were necessary to develop a system which acquire and accumulate and provide XRAIN observation information. The next three problems involved large-capacity data, which were divided into particular areas in real time. 1. Processing delay; 2. Overlapped data; and 3. Low presentation speed. In this study, suggestions and implementations for the purpose of "rapidly providing urgent information during disaster prevention" were provided to address these problems. In this section, background for each problem, suggestions for improvement, and implementation results are described.

A. Parallelization for Reducing time of the delay

1) Limitation of processing time:

XRAIN data have uneven volume in terms of rain strength, the volume of data tend to be large. Because of this, transfer from MLIT delays or fails, and data loss may occur when a local heavy rainy area lies scattered. Therefore, the data transferred time and the transferred order for every area change according to the situation and are not constant. There are cases where the 14 files are not kept within 1 minute of the transfer interval.

On the other hand, the load of the systems is always high due to various demands such as downloading or browsing by users, which occurs along with XRAIN processing (this refers to “acquisition, accumulation, visualization”) on DIAS. The fact that all processing must be completed within one minute was a problem in development. Actually, when XRAIN processing was implemented sequentially for all areas, the total processing time was over 1 minute, and delays were observed.

First, it is necessary to finish all XRAIN processing within 1 minute of the data transfer interval. On the other hand, it is necessary to have time to spare for the next transfer given unexpected processing events such as reprocessing with data distribution delays or requests for data downloading or browsing by users. Thus, "letting XRAIN processing complete by the next transfer start; for a total processing time of less than 1 minute" was assumed to be a problem target.

2) Parallelization:

Because delays occurred with sequential processing, it was decided that parallelization was appropriate for almost all processing. Specifically, the next content sample was suggested. (Fig. 9)

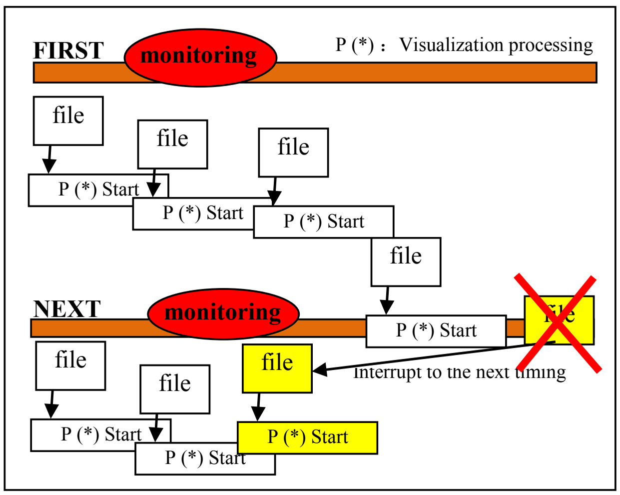

Fig. 9. Practice image of the parallelization

[Methods]

1. Having top priority among all "XRAIN processing for the current time."
2. All processing carried out in parallel, and the completion situation is monitored.
3. Reprocessing of delay data and all processing except 1. are carried out as an interrupt.

3) Evaluation of the proposed method:

As a result of having carried out XRAIN-related processing for data from April, 2015 according to this suggestion method, the total processing time was less than 42 seconds, and improvement in the transaction speed was observed. Thus, the present conditions do not have a delay. In addition, in comparison with a targeted value of 60 seconds, approximately 30% of present conditions are able to afford time.

However, when data increases with the expansion of the observation area, the processing time may be beyond the transfer interval; in that case, the examination of the addition methods become to be necessary.

B. Making of the synthetic image by a method given priority due to high risk

1) Factor of overlapped data

The synthetic rainfall of XRAIN is coordinated by the observation information of multiple radars, but they are carried out in each area separately, and adjustment between areas is not performed. Therefore, the adjustment result for synthetic rainfall varies by the information obtained in each area if one location is covered by multiple areas.

The phenomenon is shown in the image (Fig. 10 and Fig. 11) of "heavy rain in Kanto and Tohoku in September 2015". The image of the Toyama area (Fig. 10) and the image of the Kinki area (Fig. 11) at the same time are shown, and each arrow points to the same spot (the southwestern part of Lake Biwa). In both, the left image shown is a local overall image, and the right image is an extended image of the target spot. The point that is shown with an arrow is included both in the Toyama area and the Kinki area; the strength of the rain displayed in each is different for the same location. The area shown in red in Fig. 10 shows heavy rain; this observation information expresses high risk, but the information concerned is not detected in Fig. 11.

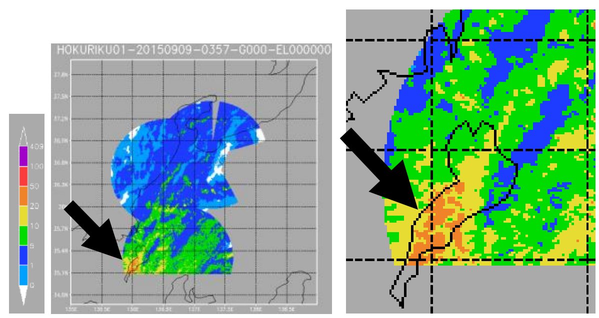

Fig. 10. Toyama (2015/09/09 03:57 JST)

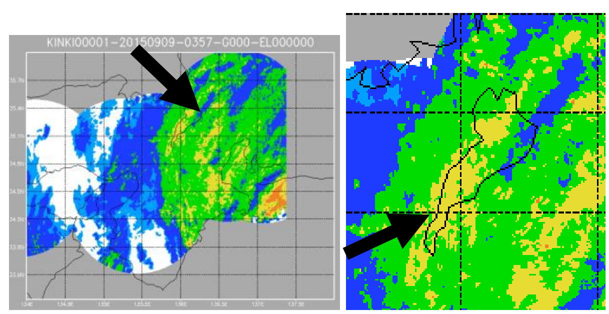

Fig. 11. Kinki (2015/09/09 03:57 JST)

In this example, the radar for XRAIN in the Kinki area (black circle in Fig. 12) was not able to acquire localized burst information that was acquired by an XRAIN radar in the Toyama area (red circle in Fig. 12) because the decrements of the radar wave blocked by heavy rain. For synthetic rainfall in the location concerned, adjustment of the value was carried out within Toyama and Kinki, respectively, but the values were not compared and were left unattended. As a result, although the location was the same, the transferred information is different.

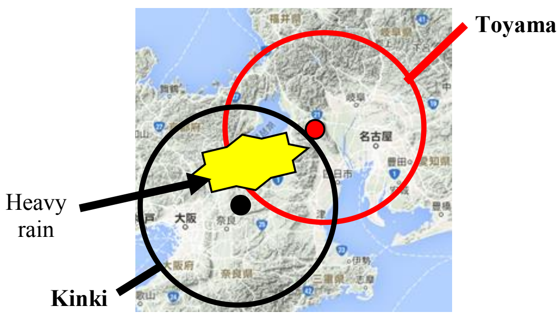

Fig. 12. Main radar setting image around heavy rain

The transfer information for the same location should be decided uniquely, but the transfer information varies for the same spot as shown in this example. Thus, users are confused, the risk in the area is overlooked and users are prevented from taking appropriate action.

There is overlap for transfer data from MLIT, but to change the value on the transfer side is difficult. Therefore, it is necessary to remove overlapped data in DIAS at reception and plan for data unification.

2) Suggestion of method given priority to high risk

As for the significance of the information sharing of XRAIN, disaster prevention measures are considered to be the first purpose in this study. Therefore, information regarding high strength should be displayed by the suggestion methods based on the precedence for every spot because observation information of high rainfall strength be characterized by high risk. In this way, the methods to determine strong values (high-risk) of rainfall strength is defined as the "high risk priority method" for cases where plural observation data exist in one spot. Problems where there is plural information in the same spot are solved by this method, and information regarding high risk is rapidly made available.

In this study, information is managed according to each area and is composed as a whole Japan image by applying high risk priority method. Outline of the processes are as follows. First, files of 14 areas are read sequentially. Then, the suggestion method is applied, and a value is set. This is carried out for all 14 files, and the whole Japan image is composed. (Fig. 13)

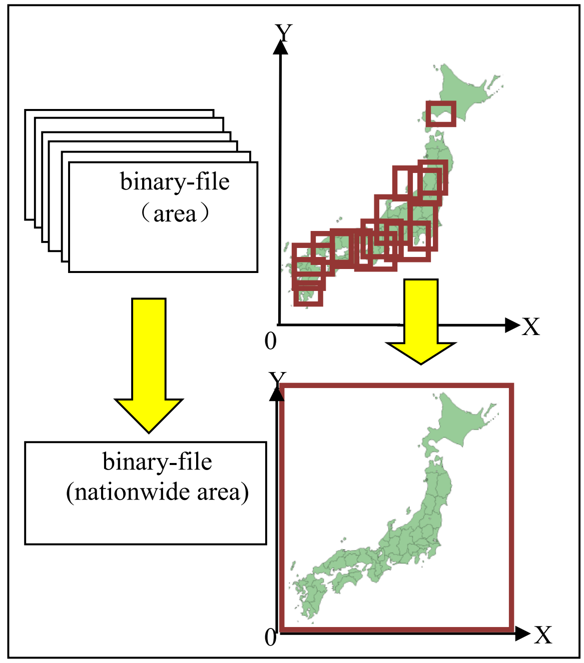

Fig. 13. Image of the suggestion method

1. An initial value "-9999" is set for the data (the two dimension sequences that gave the positional information for nationwide area) for all pixels.
2. When the value of the pixel is larger than the value that was already set for the same pixel, the larger one is adopted.
3. In cases other than the 2 above, the value that was previously set is adopted.

3) Result of the proposed method

An implementation result based on the suggestion method is shown in Fig. 14.

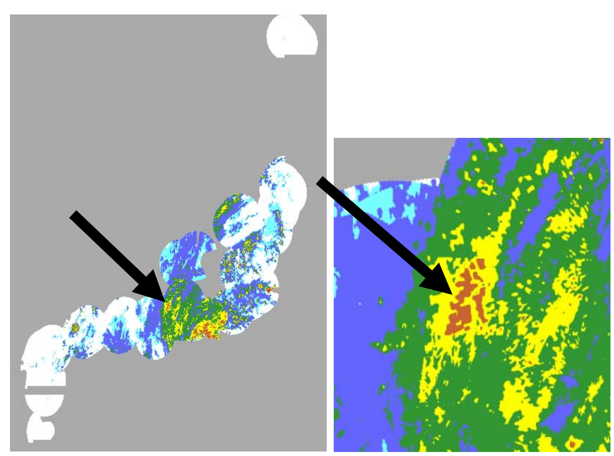

Fig. 14. Whole Japan synthetic image according to method giving priority to high risk (2015/09/09 03:57 JST)

A whole Japan image was composed of pieces of observation information for the 14 areas. The observation information for heavy rain displayed in Fig. 10 is given priority over the observation information in Fig. 11 as indicated by the arrow directed at the extreme high observation information. In this way, a system that displays high-risk information after evaluating values based on the observation information of every location was implemented, and overlapped data were removed.

However, the implementation result based on the methods giving priority to high risk was excluded from object downloading by researchers and made available only to users for browsing. Because users might be confused when data processed based on the suggestion of this study and data generated by MLIT are intermixed in DIAS. However, the method to provide these data in the future is examined because the use expectations of the implementation result increase.

C. *Speedup of presentation speed by the high value adoption-type compression method*

1) Problem regarding the quantity of transmission data at the time of extended presentation:

As for the browsing of XRAIN information for general users, handheld devices such as cellular phone and smartphone are enabled for the sake of convenience. However, performance was low, and this improvement was considered to be a problem when a particular presentation was carried out.

Images corresponding to the present location information of users are displayed on a map using this function. In the case of this presentation, images displayed according to an appointed scale are changed to one of the local images or whole Japan synthetic images. A problem occurred when the indication of the local image was changed to the indication of the whole Japan image. It was required because in some cases it was not displayed even it passed for a long time from the designation of the change. The whole Japan synthetic image is 78MB, 39-111 times greater than the local image which is 0.7MB - 2MB. Therefore, it was thought that with the main factor, the size of the information of this whole Japan synthetic image lowered performance.

On the general homepage, it is noted that the users feel stress after three seconds for waiting time before information being displayed. Therefore, regarding XRAIN information browsing for general users, the purpose was to change a local image to a whole Japan image, achieving a waiting time of less than 3 seconds.

2) Suggestion of the high price adoption-type compression method:

For performance enhancement of the presentation, a reduction in the information for the whole Japan image was attempted. First, the next two plans were considered reduce the number of pixels of the whole Japan image by a quarter.

a: The maximum of the inside is extracted every 2 pixels in every direction, and the value is set for a value of 1 pixel, representative of 4 pixels.

b: The mean is extracted every 2 pixels in every direction, and the value is set as 1 pixel, representative of 4 pixels.

Because XRAIN information is local information, the observation information of a certain spot may indicate heavy rain, but an adjacent pixel may not reflect a similar state. Therefore, in the case of "b" plan, high risk information may not be expressed when strong extreme observation information detected in a certain pixel is treated for the mean using an adjacent pixel. It was thought that the result of the "b" plan was undesirable from the viewpoint of disaster prevention, and "a" plan was adopted in this study. This method is defined as "high price adoption-type compression method".

Specifically, the strength of the rain is evaluated every one pixel, and the highest value is set as representative of 4 pixels concerned. (Fig. 15)

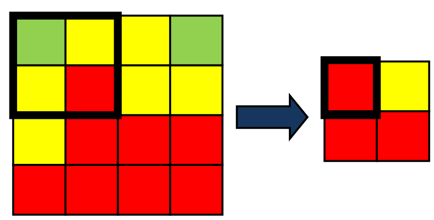

Fig. 15. Image of the suggestion technique

3) Evaluation of the proposed method

As results of having implemented this method, performance in presentation improved because the quantity of transfer was held down to a quarter. The present conditions achieve presentation in less than 1 second after a change was appointed in more than 90% of examples, and this is approximately one-third of the target, i.e., 3 seconds. In addition, a result equal to the objective was provided information of high risk rapidly because using this method could display information of heavy rain without an omission. Furthermore, users change it to the original local image for every area by extending a scale, and they can confirm the original strength of all spots. Because users quickly determine whether an area is high risk, it is suitable for risk management in disaster prevention.

V. Conclusion

In this paper, implementation results were introduced as new suggestion methods for three problems that occur in handling XRAIN, for which large-capacity and real-time processing are necessary. All the suggestions are performed to "Develop an information platform of XRAIN where the acquisition, accumulation, and providing of information are carried out in real time and can contribute to disaster prevention management"; in addition, it is shown that this purpose was achieved.

For processing delays, we sorted high-priority processing and achieved efficiency improvements of more than 40% by making all data processing parallel. In this way, we were able to develop information platform of XRAIN where the acquisition, accumulation, and providing of information are carried out in real time. Then, about the problem that overlapped data has occur because of transfer unit divided to each area, we carried out the solution to the problem by making a whole Japan synthesis image using the high-risk priority method on DIAS as the receiver side. Thus, we kept the integrity of data and were able to present to users potential high-risk information with precedence. Finally, regarding the low presentation speed at the time of the scale reduction in the presentation screen of the user, we tried reducing the quantity of data transfer to around a quarter according to a high-value adoption-type compression method. By this way, rapid presentation was realized. Therefore, we were able to develop a system that achieved the objective proposed above.

This system was begun to operate in April, 2016, and various studies using XRAIN data were initiated. The essential significance of DIAS rests in the value created by the data as well as the ability to accept large-capacity data. Because information is gathered in one place, other data can be incorporated, and new data values are created; a spiral-like growth of the whole information platform is expected. XRAIN data are extremely useful to obtain information regarding localized burst, and future studies are expected as results of this outcome. Based on the results of this study, new values to XRAIN information accumulated in DIAS are brought by users, and growing up, which are extremely important as an initial purpose of DIAS. If these results can contribute to disaster prevention measures with respect to flooding caused by localized burst in Japan, we are pleased.

Acknowledgment

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