Proposed Method for Disaster Prevention-Oriented Synthetic Rainfall of C-band radar and XRAIN

Hitomi Sano
Ochanomizu University,
The University of Tokyo
Bunkyo-ku, Tokyo
112-8610 Japan
sano@tkl.iis.u-tokyo.ac.jp

Eiji Ikoma
The University of Tokyo
Meguro-ku, Tokyo
153-8505 Japan
eikoma@tkl.iis.u-tokyo.ac.jp

Masaru Kitsuregawa
National Institute of Informatics,
The University of Tokyo
Chiyoda-ku, Tokyo
153-8505 Japan
kitsure@tkl.iis.u-tokyo.ac.jp

Masato Oguchi
Ochanomizu University,
Bunkyo-ku, Tokyo
112-8610, Japan,
oguchi@is.ocha.ac.jp

ABSTRACT

In recent years, the phenomenon of localized bursts of rainfall has increased in Japan. For this reason, collecting and sharing rain information quickly is the most important issue in terms of disaster prevention measures related to water disasters. XRAIN, which is suitable for the observation of localized heavy rain, enables high resolution observations and drastic shortening of observation times. However, the observation area of XRAIN does not cover all of Japan. Conversely, C-band radar, which is suitable for wide-area observation, covers the entire country of Japan, but it has difficulty to observing localized heavy rain. Both radars have opposite characteristics. For this reason, we examined a method that complements observation information from XRAIN with that of C-band radar to determine the rain situation in all of Japan, including localized heavy rain. In this study, we also proposed a method that synthesizes observation data of XRAIN and C-band radar and uses our proposed disaster prevention-oriented method. As a result, our method made it possible to display observation information throughout Japan, including localized heavy rain, in real time. The proposed method and implementation results are described in this paper.

CCS CONCEPTS

• **Information systems → Information systems applications**; Data mining; **Data management systems;** Information integration;

KEYWORDS

XRAIN; X-band MP radar; C-band radar; Water disaster; Disaster management; Disaster prevention; Synthetic rainfall; Precipitation

ACM Reference format:

H. Sano, E. Ikoma, M. Kitsuregawa, and M. Oguchi. 2018. Proposed Method for Disaster Prevention-Oriented Synthetic Rainfall of C-band radar and XRAIN. In Proceedings of *12th International Conference on Ubiquitous Information Management and Communication, Langkawi, Malaysia, January 5-7 (IMCOM'18)*, 6 pages.

https://doi.org/10.1145/3164541.3164607

IMCOM '18, January 5–7, 2018, Langkawi, Malaysia

ACM ISBN 978-1-4503-6385-3/18/01…$15.00
https://doi.org/10.1145/3164541.3164607

1 INTRODUCTION

In Japan, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) introduced the eXtended RAdar Information Network (XRAIN) to observe local rain. XRAIN is an observation network of X-band MP radar that the MLIT manages. As shown in Table 1, XRAIN enables 16 times greater resolution compared to C-band radar as well as providing faster observation (1 minute).

Table 1: Comparison of C-band Radar and XRAIN

Radar	C-band	XRAIN
Observation interval	5 min	1 min
Transfer interval	10-15 min	1 min
Spatial resolution	1 km	250 m
Frequency	5 cm	3 cm
Observation area	Radius 120 km	Radius 60 km
Transfer unit	nationwide area	local area

Data volume	100 KB / 5 min	20 MB / 1 min
(approximate)	30 MB per day	30 GB per day

However, because of the short XRAIN wavelength, shielding often blocks the radar wave progress. Therefore, the observation areas of XRAIN are limited and cannot cover all of Japan. Representative information that complements information outside the observation range of XRAIN is C-band radar, but it is difficult to observe local rainfall. Therefore, if a disaster area due to local heavy rain occurs outside the XRAIN observation range, it is necessary to investigate using other rainfall information, which hinders the deployment of rapid disaster countermeasures.

Therefore, in this study, we examined the method of simultaneously displaying localized heavy rain information while complementing the XRAIN observation area with C-band radar. However, as shown in Table 1, both radars have different delivery intervals and different resolutions. Therefore, we proposed a method to prioritize high risk information as disaster prevention. As a result, it becomes possible to display rainfall information of the entirety of Japan, including local downpours, and it is possible to expect useful information for water disaster countermeasures. In this paper, we introduce the proposed method and the implementation result.

2 RELATED WORK

Since XRAIN handles large amounts of data, it was difficult to construct an environment for sharing information in MLIT. Therefore, all XRAIN information has been accumulated in Data Integration and Analysis System (DIAS) [1], which is a global environmental information platform with the largest capacity in Japan. In DIAS, development aimed at information sharing of XRAIN was conducted [2][3] and operation started in July 2014. In addition, because real time processing of a large volume of data is required, high-speed processing mechanism was also realized [4][5][6]. In this way, DIAS is an infrastructure that contains the most of domestic information on XRAIN.

XRAIN has the problem of radar wave attenuation. Related research work was performed on correction accuracy [7]. However, how to deal with the XRAIN deficiencies was not discussed. There are also studies on a cumulative rainfall monitoring system [8] and rainfall prediction [9][10][11][12] using XRAIN. However, because the target is XRAIN only, the observation scope is limited, and many areas in Japan are out of scope, and XRAIN is not sufficient for disaster prevention measures throughout Japan.

Currently, there is no method to synthesize rainfall for all of Japan probably because there is a limit to construct an environment that has enough capacity to store XRAIN data. For this reason, we developed a system using the DIAS environment with notably large storage capacity.

3 CHALLENGES FOR PROVIDING RAPID RAINFALL INFORMATION

First, we compare the information of C-band radar and the nationwide synthesized information of XRAIN for the same dates and times (Figs. 1 and 2).

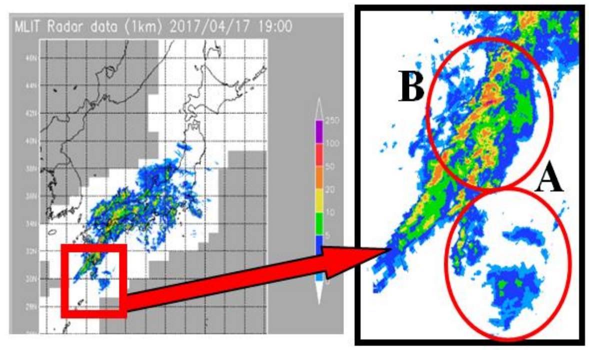

Fig. 1: C-band radar (2017/04/17 19:00 JST).

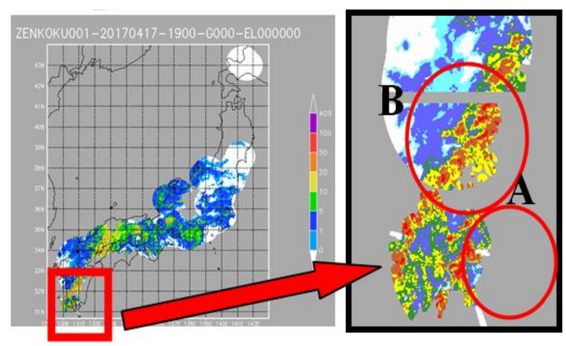

Fig. 2: XRAIN (2017/04/17 19:00 JST).

By referring to the results of both radars, the following conclusions can be drawn. First, the observation area of the C-band radar is wide, and the rainfall information in the area outside the XRAIN observation range (the area shown in gray) is detectable by the C-band radar (A in the figures). Next, the local heavy rain detected by XRAIN is not detected in the C-band radar observation area (B in the figures).

The observation information of XRAIN and C-band radar differ in distribution interval and resolution. Therefore, concurrent data in XRAIN may not exist in the C-band radar. Additionally, since the resolutions are different, in order to synthesize the results, it is necessary to match the resolutions; therefore, a method for solving these problems is required.

4 OUTLINE OF SUMMARY PROCESSING ON DIAS

DIAS has super-large capacity storage of approximately 25 PB (as of August 2017), vast analysis space and many server clusters; it can carry out acquisition, accumulation, unification, and analysis of data provided by global observation and simulation. A huge volume of accumulated data and various data handling applications and analysis tools are available on DIAS.

In this study, we developed a new infrastructure of rainfall information on DIAS using C-band radar information and XRAIN information accumulated on DIAS. Fig. 3 shows an overview of the overall processing from the reception of C-band radar information and XRAIN to the synthesis of both. The development carried out by this study is shown in the bold frame.

Observation information from the C-band radar is transferred to DIAS from MLIT as nationwide data; the transfer interval is 5 minutes. XRAIN data are transferred from MLIT to DIAS in units divided into 14 regions; the transfer interval is 1 minute.

Both radar processes perform data accumulation and processing immediately after data acquisition in DIAS. XRAIN processing is performed to synthesize nationwide regional information. Finally, synthetic rainfall of XRAIN for the whole country and observation information of C-band radar are synthesized.

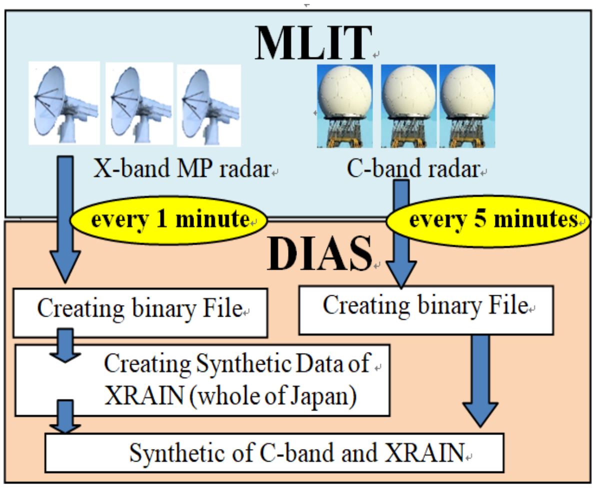

Fig. 3: Outline of summary processing on DIAS.

5 PROPOSAL OF DISASTER PREVENTION-ORIENTED METHOD FOR SYNTHETIC RAINFALL INFORMATION

The intervals of transfer time and spatial resolution are different for C-band radar and for XRAIN. For this reason, consideration of the interval and resolution is required before synthesizing information from both radar types. If the observed values from both radars at the same spot are different, it is necessary to consider which value to adopt, as discussed in the previous section.

The purpose of this study is to promptly provide high-risk information for disaster prevention. From this viewpoint, we propose the following. First, adjust the interval and resolution of both radars to XRAIN information. Next, the spot where the information of C-band radar and XRAIN overlap should be set preferentially with a higher risk value of both. Finally, an algorithm is required for implementation. We call this the "disaster prevention-oriented method" and propose a new method to synthesize rainfall information from C-band radar and XRAIN.

We propose the method consisting of 1. adjustment of the time interval in the dual radars; 2. adjustment of spatial resolution; and 3. selection method of rain intensity of both radars at the same point, introduced in order.

5.1 Adjustment of the time interval

The transfer from MLIT to DIAS is in real time, but because the interval of the observation time of both radars is different, the acquisition timing and the data acquired in DIAS from both radars are different. For this reason, the timing of processing and target data were examined.

First, we considered the idea of synthesizing XRAIN data at the same time as C-band radar data. In this case, the processing time for creating the synthesized data is every 5 minutes, and the frequency is one-fifth compared with the case of synthesizing data according to XRAIN. Even if information on local heavy rainfall from XRAIN is detected 1 to 4 minutes ago, it cannot be reflected. If we synthesized the average value of XRAIN observations in the last 5 minutes with the information from C-band radar, the strong rainfall information that XRAIN can obtain is weakened by the averaging process, and there is a possibility that information on high risk will not be detected. Therefore, if XRAIN is adjusted according to the C-band radar and information from the two is synthesized, the frequency of processing is lowered, and local heavy rain information with strong intensity cannot be reflected in a timely manner.

From the viewpoint of risk management and disaster prevention, it is considered appropriate to quickly detect high-risk information; therefore, we determined that it is appropriate to adjust the timing to match XRAIN, whose processing frequency is high. C-band radar acquires information hourly at 5-minute intervals, i.e., 0:00, 0:05, 0:10, etc. The values of C-band radar are the average values of rainfall in the past 5 minutes. For this reason, we propose a method of complementing the data from 1 to 4 minutes before the value of C-band radar is recorded with the data of the latest C-band radar and then combining that data with the data of XRAIN. The specific method is shown in Fig. 4.

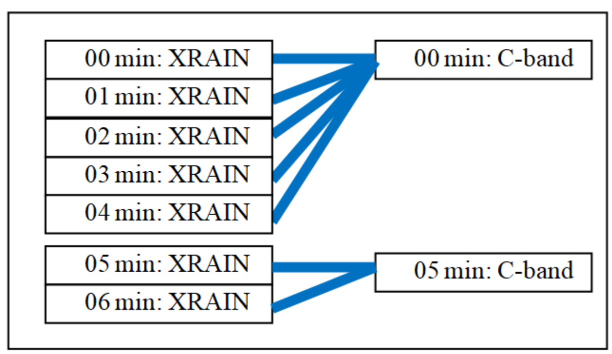

Fig. 4: Image of Spatial Resolution Synchronization.

5.2 Adjustment of the Spatial Resolution

To detect local heavy rain information, high spatial resolution is necessary. For this reason, we proposed the resolution adjustment of the C-band radar to that of XRAIN. As a processing outline, one pixel of C-band radar is divided into 16 pixels (250 m square), and the original C-band radar value is set for each pixel. Next, the value of each pixel is compared with the value of XRAIN, as shown in Fig. 5. Additionally, these summary images are shown in Fig. 6.

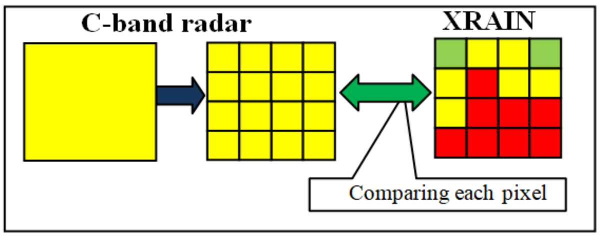

Fig. 5: Image of Spatial Resolution Synchronization.

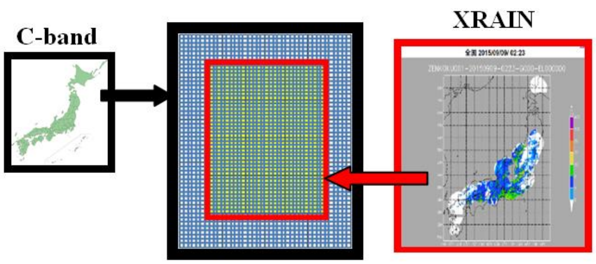

Fig. 6: Synthesize processing outline.

5.3 Selecting-Value Method at the Same Point

The XRAIN observation area is included in the observation area of the C-band radar. For this reason, we discussed which value should be adopted at the point where they overlap. We examined the issue from the viewpoint of disaster prevention and considered the following three algorithms.

Algorithm (a): Compare the values of both radars and use the larger one.
Algorithm (b): Use the uniform XRAIN value.
Algorithm (c): Calculate highly reliable values based on measured values of other rainfall information.

First, we investigated Algorithm (c). When reliable rainfall information is detected at a certain point, it is necessary to calculate the data from all the rainfall information included at that point. In Japan, we accumulated various rainfall information; however, it is a wide area of information and is difficult to obtain locally; observation points are limited. For this reason, when calculating rainfall intensity at a point, it is necessary to calculate rainfall information based on various factors, such as wind direction, topography and position information. Additionally, approximately 1 hour is required to incorporate all rainfall information as elements; therefore, it is impossible to detect changing weather information over a number of minutes in real time. Therefore, the adoption of either Algorithm (a) or Algorithm (b) was deemed appropriate in this study.

Next, Algorithm (a) and Algorithm (b) were investigated. In general, XRAIN is superior to C-band radar for the detection of localized heavy rain. However, in the case of obstacles and heavy downpours, since XRAIN uses short wavelengths, missing data may occur. In this case, it is appropriate to complement the missing data by C-band radar; therefore Algorithm (a) was adopted as a candidate.

The A proposal is a development of the previous method proposed for elimination of XRAIN data duplication.

This method is as follows. XRAIN data delivered from MLIT are delivered as 14 files divided into 14 regions across Japan. However, since duplicate data at the same point were mixed in each file, we eliminated the duplicates and secured the data consistency. The specific example is shown in the Fig. 7.

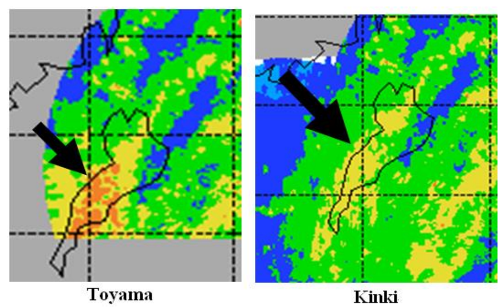

Fig. 7: Synthesized image of the region (2015/09/09 03:57 JST).

Among the 14 regions divided by XRAIN, the one on the left is Toyama, and the one on the right is Kinki; the same point is included in the regional information, and the values are different. As described, in XRAIN, the value of one point occasionally overlaps with plural regions. However, even if the value at that point differs between regions, no adjustment is made between them. As a result, the differing point value are included in the distribution file as duplicate data. To eliminate this duplicate data, we proposed a high-risk priority method and secured data consistency. When the values are different at the same point, the larger value is regarded as information with high risk, and in view of disaster prevention, the value with higher risk is displayed with priority.

In the synthesis of multiple radar data information, we developed this method and proposed it as the disaster prevention oriented method.

6 IMPLEMENTATION RESULT

We synthesized the information of C-band radar and XRAIN at the same date and time by the proposed method. The implementation results are shown in Fig. 8.

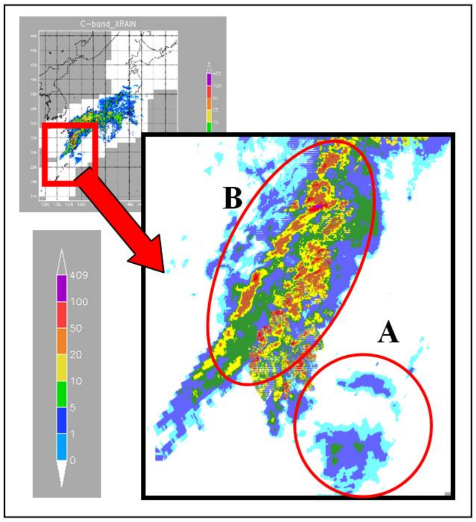

Fig. 8: Synthesized image by the proposed method (2017/04/17 19:00 JST).

Fig. 8 shows that the information from both radars complement each other. First, the C-band radar data supplements the observation XRAIN range for rainfall information in areas outside (A in Fig. 8). In addition, XRAIN supplements the C-band radar data for local heavy rain information that could not be detected (B in Fig. 8).

The radar value that was adopted at the overlapping point of both radars at this time indicates the number of pixels (Table 2).

Table 2：Radar Pixel Percentages

	Pixel	%
C-band radar > XRAIN	1813352	8.85
C-band radar < XRAIN	2005690	9.79
C-band radar = XRAIN	2037506	9.94
C-band radar missing and XRAIN >= 0	418685	2.04
C-band radar >= 0 and XRAIN missing	14213852	69.4

Table 2 shows that the area covered by the C-band radar in the region where XRAIN is missing is approximately 69.4%, and the region outside the observation range of XRAIN is supplemented by the C-band radar. In addition, the rate at which XRAIN supplemented strong rainfall information more strongly than C-band radar is 9.79%, and it was confirmed that information based on XRAIN was synthesized.

In addition, the case where C-band radar's rainfall intensity is stronger than XRAIN rainfall intensity is also shown as 8.85%. Regarding this finding, enlarged views of the implementation results of Algorithm (a) and Algorithm (b) are shown in Fig. 9.

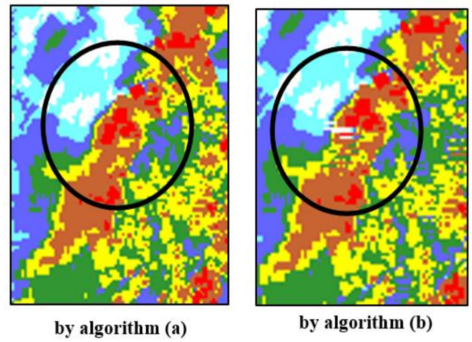

Fig. 9: Enlarged view of the synthesized image (2017/04/17 19:00 JST).

The circled areas in figure are the information that is not continuous in Algorithm (b). However, the value of XRAIN in this section is not missing. The observation information of XRAIN could not be observed as strong intensity information of due to attenuation of the radar wave. This is supplemented with the information of C-band radar in Algorithm (a), and continuity with surrounding rain intensity is secured. Therefore, if we adopt Algorithm (b) and prioritize the value of only XRAIN, this case will be undetectable, so we can conclude that it is appropriate to adopt Algorithm (a).

As a result, the proposed method in Algorithm (a) can synthesize information from multiple radars, complement each observation range and altitude of rainfall, and provide high-risk information.

When synthesis processing is executed at the time interval of XRAIN, all synthetic processing must be completed within 1 minute. We implemented high-speed XRAIN processing in a previous study and reduced processing time to approximately 40 seconds on average. Therefore, there is a margin of 20 seconds on average, and even if synthesis processing with C-band radar is added, there is a margin of roughly 10 seconds on average.

7 CONCLUSION

In this paper, the proposed disaster prevention-oriented method combines rainfall information obtained by a plurality of radars to provide high-risk information quickly. By applying this method, it is possible to obtain in real time synthesis results, making full use of the advantages of each radar for various observation ranges and precipitation intensity. Thus, it is possible to detect observations throughout Japan, including local heavy rainfall, to assess risk.

Heavy rain occurs frequently in Japan, therefore, it is difficult to immediately discriminate between ordinary rain and the start of extremely dangerous, heavy rain. For this reason, the detection of an impending crisis is delayed, evacuations cannot be made in time, and many people are affected by the disaster.

Rather than spending time to obtain the numerical values with a rain gauge, we prioritized quickly providing high-risk information in real time. We are convinced that the proposed method will help protect people from disasters. Identifying rainfall situations in real time by the proposed method is useful for detecting signs of dangerous heavy downpours, judging behavior, and reducing damage caused by disasters.

Creating a new value as a result of fusing multiple pieces of information is an important way to utilize big data. The results of this study offer new values for generating and providing high-risk information on rainfall in real time by combining multiple radar observations and balancing the mutual advantages and disadvantages of each radar system. We hope that this proposed method will contribute to the prevention of future water-related disasters.

Acknowledgments

This study received the support of the Ministry of Education, Culture, Sports, Science and Technology study trust business "Global environment information unification fusion program (DIAS-P)" and "Global Environment Information Platform Development and Promotion Program (DIAS-PF)". Additionally, this work was partly supported by JST CREST Grant Number JPMJCR1503, Japan.

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