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Development of Sediment Flash Flood Disaster Early Warning System based on X-band Radar

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Abstract

The research visit conducted in the Research Center for Urban Safety and Security of Kobe University was aimed to study development of sediment flush flood disaster early warning system based on X-band radar. Under SATREPS activities, several researches and discussions through workshop and training were conducted in order to enhance disaster resilience caused by volcanoes activities. By using recent radar technology development, namely X-band multi-parameter radar (XMPR), actual rainfall intensity occurrence is precisely measured than using single parameter. Rainfall is well-known becoming a significant factor triggering sediment flush flood, especially those with high intensity and short-term duration, therefore the accuracy in measuring rainfall occurrence is very important. More accurate actual rainfall intensity measured, better rainfall prediction would be generated. By using multi parameter radar the attenuation problems which frequently occur in conventional radar could be diminished by the presence of such parameters as horizontal wave echo (Z_h), vertical wave echo (Z_v), differential reflectivity wave echo (Z_{DR}), specific differential phase parameter (K_{DP}), and coefficient correlation (ρ_{vh}).

A method used in short-term rainfall forecasting still needs to be developed to improve its accuracy. A combination of multi parameter radar and numerical weather prediction based on advection model has given a good prediction for both rainfall intensity rate and rain cloud movement. By using advection model, the rainfall movement within 1-2 hours forward has been accurately predicted. However, the rainfall growth and decay predictions are still remain challenge to be improved. The presence of physical components contributing to precipitation may take into consideration to generate a better short-term rainfall prediction. Other drawback is the computer's memory limit in translating a series of radar data that would reduce the accuracy of rainfall intensity measurement, especially for the duration longer than 2 hours, and even simulation sometime cannot be done.

In practical use short-term rainfall forecast could be well developed by using LabVIEW Software. By using LabVIEW Software, a complex numerical algorithm could be modeled with more attractive and much simpler script compared to other programming language such as C, C++, and Java. Remain challenge in radar application concerning several issues as like establishing an ensemble of radar combined with early warning system for risk mitigation purpose, a proper radar-rainfall algorithm used for tropical-latitude area, and troubleshooting of a poor radar data access system.

1.OUTLINE OF THE RESEARCH VISIT

My visit to Kobe University was conducted in a series of SATREPS (Science and Technology Research Partnership for Sustainable Development) program for join cooperative research involving

government and higher educational institutions between Japan and Indonesia Country. The research affiliated with Prof. Satoru Oishi laboratory, namely the Research Center for Urban Safety and Security, Organization of Advanced Science and Technology, started from October 15, 2015 until November 20, 2015. The main purpose of research was to study X-band radar aimed to develop a sediment flash flood disaster early warning system. The activities included discussions, site visits, and some lectures and trainings on radar system.

The radar training took place in Kobe campus, on November 2 to 5 with the participants from Indonesian Government Institutions involving BPPT (Agency for the Assessment and Application of Technology), BMKG (Agency for Meteorology, Climatology and Geophysics), and Ministry of Fisheries and Marine Resources. On November 9 to 12 the research activity was conducted in Yogyakarta taking part of SATREPS workshop and continued with establishment declaration of the Merapi Consortium involving government institutions, civil society organizations at Mt. Merapi and higher educational institutions.

The topics that I studied during the research included Doppler radar signal theory and spectral estimation, short-term rainfall forecast method, and development of X-band radar with its application on flash floods disaster modeling. Moreover, I studied on programming language using LabVIEW aimed to radar data processing for short-term rainfall forecast. Several activities conducted during the visit are described in more detail as follow.

2.FIRST WEEK: RADAR INTRODUCTION AND STUDENT SEMINAR

The commence meeting with Prof. Oishi was taken at RCUSS (Resilience Centre of Urban Safety and Security) building, started with short introduction about the campus facilities then continued with managing several agendas during my visit. My agenda at first week was to study Polarimetric Doppler Weather Radar and programming languages by using LabVIEW. During this time, Prof. Oishi and I discussed more about general concept and basic theory of Polarimetric Doppler radar. Furthermore, Prof. Oishi explained a working principle of radar system and the application on rainfall intensity measurement. I also shared some engineering programs that I commonly used for hydrological modeling.

Besides my study activities, Prof. Oishi asked me to attend the student seminars for both undergraduate and master levels. The students' research mainly discussed about radar application in recent hydrometry technique, which was interesting. Some of them were about the analyses on electrical energy emerged from raindrops collision, ice particle measured in clouds, and lightning intensity occurrence simulation triggered by volcanic ash bursts. Discussion on this session has taught me that radar application would be very useful for a variety purposes concerning on hydro-meteorological modeling in the near future.

3.SECOND WEEK: PROGRESS MEETING

Further meeting with Prof. Oishi was conducted to give a short report about my study progress during the first week of research visit. I reported such methods used for predicting a short-term rainfall intensity based on literatures. Current now casting techniques for short-term rainfall prediction are classified into: prediction based on explicit solution of numerical equation, physically-based conceptual model, and translation model using advection vector. Such explicit solutions used in stochastic approach are known appropriate in practice where weather radar or other instrumental forecasting is not available. Several techniques are adopted belong this method for example: Auto–Regressive-Moving-Average (ARMA), Artificial Neural Network (ANN), Neyman-Scott Rectangular Pulse (NSRP), and much more.

Rather than using a chaotic system in neural network which exhibits a strong uncertainties, a short-term rainfall forecast using physically-based conceptual model corresponds to water balance and thermodynamic mechanisms has disentangled such a "black box" process. This method has considered using such factors triggering precipitation as air moisture, water vapor rate, wind, cloud temperature, etc. This information is known very useful for Quantitative Precipitation Forecast (QPF) even though requires the real data obtained from instrumental forecasting to be tested.

Recently, short-term rainfall forecast method applied in radar is using advection model. It has been applied in the X-band Dual Polarimetric Doppler radar developed by the Furuno Electric Company. Using

advection model, the rainfall movement within 1-2 hours ahead has been accurately predicted. This method had also been tested by Dr. Ratih Indri Hapsari with introducing an advection vector on the translation model for developing an ensemble rainfall-runoff model used for urban flood disaster in Kofu urban area. This research also concluded that the use of X-band multi parameter radar (XMP) could accurately estimate detailed rainfall distribution and rainfall intensity.

Further discussion concerned on LabVIEW applications for short-term rainfall forecast using advection translation model. The short-term rainfall forecast could be well developed by using LabVIEW, however, the memory limitations of computer equipment to read a series of radar data becomes an obstacle because then the accuracy in predicting the rainfall, especially for the duration over 2 hours, to be reduced and even simulation cannot be done.

4.THIRD WEEK: RADAR TRAINING

The first day of the radar training Prof. Yamanaka presented the history and basic theory on weather radar equipment, various observations done with weather radar, and radar reflectivity and Z/R relation (echo wave-rainfall intensity relation). The important point noticed was the need of ground rain gauge set up to calibrate rainfall intensity measured by radar. Even though radar would be equipped with such algorithm to translate radar parameter into rainfall intensity, nevertheless still ground data is required. By taking several tests between Z and R correlation, the more accurate algorithm for generating rainfall intensity could be obtained. A coherently series procedure for radar set up at commence must be followed, one of which is by installing ground rain gauge.

The second day of the radar training Prof. Satoru Oishi presented several topics related to dual-polarization radar theory with multi-parameter (e.g. Z_h, Z_{DR}, K_{DP}, and ρ_{vh}), radar scanning methods (e.g. PPI, CAPPI, RHI, SRHI, etc.), and short-term rainfall forecast using radar. Using multi parameter radar such attenuation problems which frequently occur in conventional radar could be diminished by the presence of specific differential phase parameter (K_{DP}). Even if multi parameter applied in current radar system, however, several uncertainties factors exhibits (e.g. atmosphere, terrain conditions etc.) are still remain challenge to elevate the accuracy of rainfall intensity measured by radar.

The third day of the radar training the engineering team from Furuno Electric Company presented the development of Furuno's radar from the simplest to the most advance technology. We were shown one of the Furuno's radar set up at Kobe University. We learned about the radar instruments, how to read the radar processing images with some ground clutters exist, how to find the raw radar data, how to process the radar data in practical use and much more.

The last day of the radar training, we visited Pi-Cave studio located at Integrated Research Campus of Kobe University. At this place we were shown the virtual 3-D simulation from various study results in the field of applied technology. From the virtual 3-D we were shown an illustration of such a physical image of rain clouds with some lightning captured from weather radar outlook. Another 3D illustration was about a volcanic eruption event with various solid particles released, and much more.

After visiting Pi-Cave studio, we continued to visit Riken AICS where a super-powerful computer in Japan, so-called Kei-Computer, was developed. The super-computer is an essential tool of advanced science and technology related to human daily lives, including engineering and health sciences research for example used for global warming forecast, disaster simulations, analysis for drug design, development of new devices and materials, and other uses.

5.FOURTH WEEK: SATREPS WORKSHOP

SATREPS activity was conducted in Yogyakarta from November 9 to 12. This activity included workshop and consortium establishment. An issue was carried out through the workshop concerning partnership based disaster risk mitigation, particularly related to volcanic disaster. Such comprehensive research have been conducted for over past five years on several active volcanoes in Indonesia and in Japan. Mt. Merapi in Yogyakarta, Mt. Kelud in Malang, and Mt. Sinabung in Karo District of the North Sumatra Province for instance, have known that caused many casualties while erupted. Study on these active volcanoes characteristics would encourage engineering approach technique increased in terms of disaster management. But it must be in accordance with the social aspect through community participatory.

Some topics I considered to use in my further research was regarding sediment disaster simulation, which was presented by Prof. Miyamoto and Prof. Fujita, also monitoring technique of the volcanic ash

dispersion with X-band multi parameter radar presented by Prof. Oishi, The result of it was very useful and applicable to be used as one of support decision tools dealing with volcanic disasters. In addition, some researchers presented a study related to community participatory activities in disaster risk mitigation. The study was intended to design a best data flow modeling for disaster early warning system.

On the last days of SATREPS activity, a ceremonial of Merapi Consortium establishment was conducted. The main purpose of the consortium within SATREPS program was to elevate the awareness among the member regarding the importance of increasing disaster resilience. Moreover, the consortium was coincided as a forum in terms of information and experiences exchange concerning on disaster mitigation. However, the important point come up was that the consortium's task should not be overlapping with other institution authority.

After Merapi consortium ceremonial then continued with a meeting within a small group discussion among the participant. The main discussion topic was to prepare a further action plan to follow-up the Merapi consortium establishment. One important point noticed was about the radar at Mt. Merapi, which discovered have many problems especially for data collecting. The problems occurred could be either due to lack of data access system (e.g. communication network, internet service, etc.) or miss management for radar operating.

6.FIFTH WEEK: COMPLETING REPORT

During this week I prepared a summary report of my visit activities. I also took a class for AVS lecture. The lecture mainly discussed about generating 3D visual model using Advanced Visual System (AVS) program. Using this program we could create a simulation model to resemble the real condition with sophisticated visualized. The program was interesting and very promising for further development.

7.SUMMARY AND OUTLOOK

During the visit I learned so many things about X-band Dual Polarimetric Doppler Radar (XMP) from Prof. Oishi and his colleagues also from other researchers. By the presence of horizontal and vertical wave echo, the XMP could depict the rain drop shape more precisely if compared to the conventional ones which uses a horizontal wave echo only. Therefore a better rainfall intensity rate could be calculated.

Using radar in practical hydrology field was initially not familiar for me, but now I learn that a radar system has a multipurpose used with several advantages and that would give more efficiency, reliability, and accuracy in hydrological design. Several important points that I could summarize during my research visit at Kobe University are as follow:

(1) The weather radar that recently developed is using X-band multi-parameter radar (XMPR) technology. It is equipped with such parameters as Z_h, Z_{DR}, K_{DP}, and ρ_{vh} to overcome the attenuation that may exist. Moreover, by using multi parameter radar the rainfall intensity rate could be well predicted than using single parameter radar.

(2) A method used in short-term rainfall forecasting still needs to be developed to improve its accuracy. A combination of multi parameter radar and numerical weather prediction based on advection model has given a good prediction for both rainfall intensity rate and rain cloud movement. However, the rainfall growth and decay predictions are still remain challenge to be improved. The presence of physical components contributing to precipitation may take into consideration to generate a better short-term rainfall prediction.

(3) Using LabVIEW software, a complex numerical algorithm could be modeled with more attractive and much simpler script compared to other programming language such as C, C++, and Java. However, current short-term rainfall forecast model using LabVIEW should be improved with more various additional parameters and scenarios.

(4) Remain issues in radar application that may take into further research are following: establishing an ensemble of radar combined with early warning system for risk mitigation purpose, a proper radar-rainfall algorithm used for tropical-latitude area, and troubleshooting of a poor radar data access system.

8.ACKNOWLEDGEMENTS

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Many thanks also to all those researchers who kindly made some time in their agenda to discuss with me during my visit to Kobe University. It is hard for me to decide which of these discussions were the most interesting. This was definitely one of the best research visits I could experience.

9.DOCUMENTATION SESSION

Fig.1 Prof. Yamanaka class on the radar training

Fig 2. Furuno engineer explains the radar system works

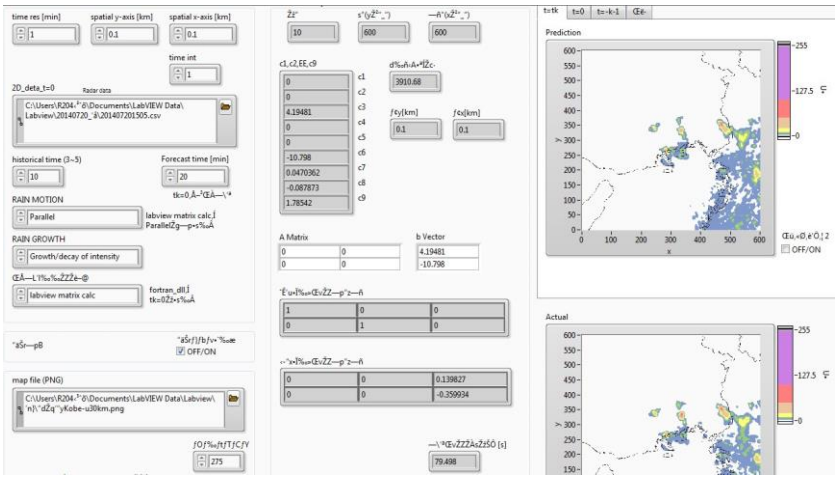

Fig 3. One of view of LabVIEW front panel for short-term rainfall forecast

Fig 4. Short briefing by Prof. Oishi during site visit to Riken AICS

Fig 5. Site visit to Pi-Cave studio

Fig 6. Ceremonial of Merapi Consortium establishment located in UGM campus

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