A Study on the Application of Flash Flood Guidance with Predicting the Risk Level of Guerrilla Heavy Rainfall

〇Hwayeon KIM, Eiichi NAKAKITA

1. Introduction

The localized severe heavy rainfalls, which have not been experienced in the past, have frequently occurred in Japan due to the effects of climate change [1]. Especially, the isolated rapidly growing single cumulonimbus is triggering a high risk for flash flood occurrence. The rapid increase of water levels can cause loss of life and property. For disaster prevention, it is necessary to analyze the initial development stage of a cumulonimbus cloud (Figure 1). Also, to make a flash flooding alert in short duration is important for saving evacuation time to escape from danger.

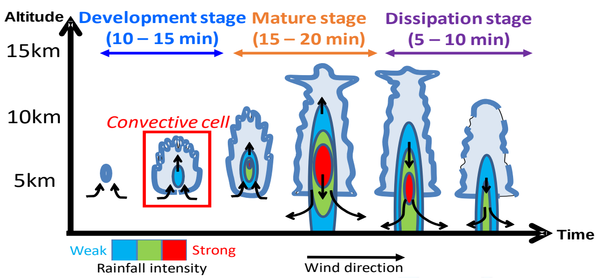

Figure 1. Life stage of the cumulonimbus cloud.

In the previous studies, Nakakita et al. [2] found that the vertical vortex tubes exist in most of the developed storm. Then, Kim and Nakakita [3] developed a quantitative risk prediction method. This method can predict whether the early detected cells become high risk level (i.e. heavy rainfall) or not. Also, Carpenter et al. [4] warned an imminent flash flood by developing Flash Flood Guidance (FFG).

Until now, predicting flash floods with sufficient accuracy and lead time to support effective response actions have been a challenging problem. The reason is because the flash flood occurs under the complex problems that integrates meteorological, hydrological and geomorphological processes. Considering these processes, predicting flash flood is essential. Therefore, this research aims to apply the flash flood guidance with the quantitatively risk prediction for the flash flood warning.

2. Data and Methodology

Rainfall and soil moisture were the main datasets to estimate the flash flood. Collecting the reliable rainfall data is most important. To provide the high spatiotemporal observation data throughout Japan, MLIT has been operating the X-band polarimetric RAdar Network (XRAIN) since 2010. Four radars (Rokko, Katsuragi, Jubusan, and Tanoguchi) were used in the Kinki region, which is our research target area. From August 2013 to August 2018, 7 GHR events are selected and the radar variables (i.e. the vorticity, doppler velocity, and reflectivity, etc.) at each event were extracted.

Also, soil moisture can be estimated by hydrologic rainfall-runoff model. It represents a hydrological cycle in watersheds based on geomorphology. A Digital Elevation Model (DEM) with 5m resolution was obtained from Geospatial Information Authority of Japan. The land use and land cover map with 500m resolution was collected from Global Land Cover by National Mapping Organizations (GLCNMO) and Food and Agriculture Organization (FAO). Then, to estimate effective rainfall on small stream, the channel cross section was obtained from Hyogo prefecture.

The early detection and quantitative risk prediction method was developed as follows. We collect the radar variables by multiple-Doppler radar analysis and set the risk level when the maximum rainfall reached the ground. Then, a multiple linear regression was defined to explain the relationship between risk level and the variables.

The FFG is estimated by Threshold Runoff (TR) and soil moisture deficit (SD). FFG is defined as the depth of rainfall to initiate flooding at the outlet of a stream watershed. TR is effective rainfall that causes a small stream to slightly exceed bankfull when the soil is fully saturated. SD is the amount of rain needed to bring the saturated soil. TR is calculated by equating the bankfull discharge and unit hydrograph. Rainfall-Runoff-Inundation (RRI) is used to simulate soil moisture and calculate SD.

3. Result and Discussion

Figure 2 shows application of FFG with the risk prediction method. The FFG was applied based on the characteristics of the study area. The area was delineated using ArcGIS into small watersheds. The soil and land use data will be used to extract the mountainous and urban watersheds. TR will be estimated by characteristics of watershed and stream on each watershed. Then, by adjusting the hydrology data to the rainfall-runoff model, the SD was estimated. TR and SD were used to estimate FFG. Finally, criterion was determined to judge the flash floods occurrence. This hydro-meteorological aspect could reflect the natural water cycle on the watershed.

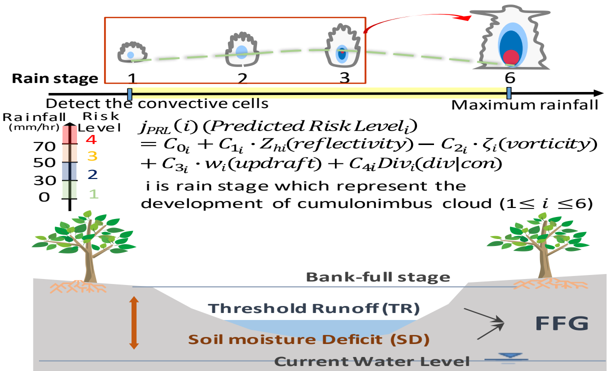

Figure 2. Flowchart of application of flash flood guidance with predicting the risk level.

4. Conclusion

In order to minimize human injury such as isolation, death, and disappearance due to flash flood, this study proposed the application of flash flood guidance with predicting the risk level for Toga River in Kobe, Japan. The quantitative risk prediction method could predict the risk of GHR development accurately. Also, FFG provides a criterion that can be used to intuitively determine whether a flash flood will occur. As the next step of this research, the quantitative risk prediction (meteorology) and flash flood guidance (hydrology) will be combined. Flash floods happened when meteorological and hydrological circumstances coexist. Therefore, future research is promising to bridge the gap between the quantitative risk prediction and the flash flood. If these methods are applied to the field, it is possible to secure enough time for disaster prevention and evacuation with high accuracy.

References

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