C201

Improvement of the quantitative risk prediction accuracy on the 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 huge damage to human 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 flooding alert is important before it is generated into heavy rainfall. In the previous studies, Nakakita et al. [2] developed a qualitative risk prediction method based on the early detection of the convective cells aloft as the radar first echo. They found that the vertical vortex tubes with positive and negative pairs did exist in most of the severely developed storm with a certain criterion. This method can predict whether the early detected cells become heavy rainfall or not, and it has been practically utilized in real-time prediction in Japan by the Ministry of Land, Infrastructure, and Tourism (MLIT).

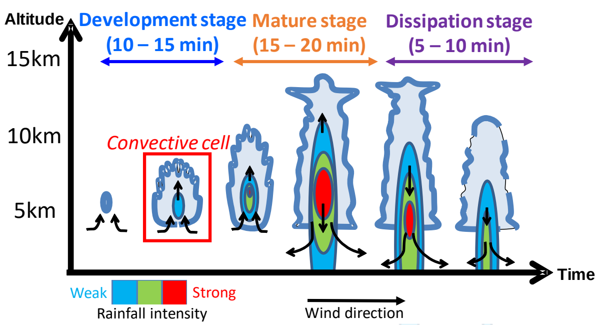

Figure 1. Life stage of the cumulonimbus cloud.

Unfortunately, the current system could predict the risk level of only two risk categories, i.e., the heavy rainfall with maximum rainfall intensity of more than 50 mm/h or not. This is still not enough to discriminate the risk precisely. So, Kim and Nakakita [3] developed the quantitative risk prediction method by using more risk levels. The early detection and quantitative risk prediction method was developed as follows. We collect and set the risk level when the maximum rainfall reached the ground. Then, we select an appropriate set of explaining variables considering the risk level. With the Receiver Operating Characteristic (ROC) analysis, we could find the most appropriate method to predict the risk level. However, we would like to improve the accuracy of the quantitative risk prediction method. Therefore, this research aims to find more relevant variables by multiple-Doppler radar analysis and represent the way to express the risk prediction precisely.

2. Data and Methodology

To provide the high spatiotemporal observation data throughout Japan, MLIT has been operating the X-band polarimetric RAdar Network (XRAIN) since 2010. As of now, the MLIT has installed 39 X-MP radars. The four radars are named as Rokko, Katsuragi, Jubusan, and Tanoguchi and are located in the Kinki region, which is our research target area. From August 2013 to August 2018, 12 GHR events are selected and the radar variables (i.e. the vorticity, doppler velocity, and reflectivity, etc.) at each event were extracted.

For improving the early detection and quantitative risk prediction method, we estimate the vertical vorticity, divergence, and convergence with real wind field data by the multiple-Doppler radar analysis. The vorticity and divergence can be interpreted as a proxy for updraft strength potential. The vertical vorticity is a measure of the local rotation of the flow. The divergence or convergence is the amount of flow entering or leaving a point. $\zeta = \partial v/\partial x - \partial u/\partial y$ and $div|con = \partial u/\partial x + \partial v/\partial y$ are the vertical component of vorticity and the divergence respectively; where (u, v) are the horizontal wind speeds. Then, to find a suitable relationship between the risk level and the variables, a linear and a nonlinear multiple regression were defined.

3. Result and Discussion

A variational method for the retrieval of the three-dimensional wind field from multiple-Doppler radar analysis was used. Figure 2 shows the reflectivity, vertical vorticity, divergence, and updraft on the development stage of guerrilla heavy rainfall. While the rain-cell developed into heavy rainfall, the updraft did exist with the vorticity, convergence, and divergence. Because the strong updraft was able to generate heavy rainfall, the vorticity and divergence might be very correlated with the risk level.

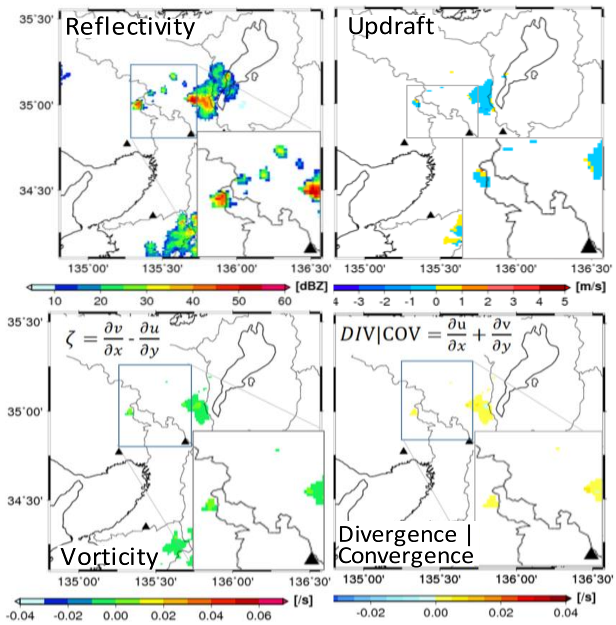

Figure 2. The development stage of convective cell at 5250m with variables on 13 August 2018.

Finally, the performances of the linear and nonlinear multiple regression were evaluated using a number of statistical performance indices such as relative error and the coefficient of determination. We can determine which multiple regression has more accuracy to represent the quantitative risk prediction.

4. Conclusion

In order to minimize human injury such as isolation, death, and disappearance due to heavy rainfall, this study proposed that the improved early detection and quantitative risk prediction method could predict the risk of GHR development accurately by using only the observed radar data. If these methods are applied to the field, it is possible to secure enough time for disaster prevention and evacuation with high accuracy. As the next step of this research, it is expected to carry out a study to predict the movement of convective cells by a short-term weather forecasting model. Also, developing the quantitative risk prediction method can bridge the gap between the method and the flash flood prediction system.

References

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