Assimilation impact of cloud radar on quantitative precipitation forecast for localized heavy rainfall: Evidence from water vapor nudging data assimilation experiments

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Meso-γ-scale localized heavy rainfall can sometimes cause human damage through the sudden rise of rivers and flooding of roads, so the development of prediction methods for sudden localized heavy rainfall is an important research subject. Numerical weather prediction (NWP) using storm-scale data assimilation is one of the techniques for very short-term prediction of localized heavy rainfall within an hour. Several studies have succeeded in predicting localized heavy rainfall by assimilating information obtained from raindrops on the development stage of cumulonimbus captured by X-band radar. However, there have been few studies on assimilating cloud information before rain formation using Ka-band radar (cloud radar), which has a shorter radio wave wavelength than X-band and can detect cloud droplets. If an appropriate cloud radar assimilation method is developed and accurate numerical weather predictions can be made within a very short time period of less than one hour, it can be a breakthrough in predicting localized heavy rainfall.

This study investigates the assimilation impact of cloud radar on localized heavy rainfall prediction. Specifically, the radar reflectivity factor (Z) observed by cloud radars was used for the assimilation, and atmosphere was moistened in the region where clouds were estimated to exist (Z >-15 dBZ). To moist the atmosphere, a nudging assimilation method was used, and water vapor was forced to increase so that the relative humidity approached 100%. The assimilation impact of cloud radar was investigated for a sudden localized heavy rainfall event on August 3, 2018. In this event, special observation by sector PPI scans of three cloud radars was carried out by NIED, and the three-dimensional structure of the generation stage of cumulonimbus which caused the localized heavy rainfall was successfully captured with high-temporal resolution of 1 minute. Using the reflectivity data of the cloud radar, assimilation (moistening) was carried out by nudging during generation stage of cumulonimbus before rainfall was observed, and prediction was conducted up to 40 minutes after nudging using Cloud-Resolving Storm Simulator (CReSS) with horizontal resolution of 700 m.

While rainfall was not predicted without cloud radar assimilation, heavy rainfall exceeding 50 mm h^{-1} was predicted about 20 minutes later with cloud radar assimilation. These results suggest that NWP with cloud radar assimilation in the pre-rain stage have a great potential for predicting sudden localized heavy rainfall. In the presentation, we will also show the sensitivity of the altitude at which clouds are assimilated and the assimilation window (timing and duration of assimilation) to rainfall predictions.

Keywords: cloud radar, data assimilation, QPF, water vapor nudging