Data assimilation of Ka-band radar and X-band radar for rainfall prediction

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Line-shaped mesoscale convective systems (MCS) often lead to events such as floods, inundation, and debris flow. Numerical weather prediction (NWP) system has limited capacity in forecasting small-scale heavy rainfall (10-100km) under weak large scale forcing conditions owing to its coarse resolution and limited small-scale data assimilation systems. Assimilation of weather radar data into NWP models can provide accurate initial conditions, because radars are the only observation systems that provide full coverage of an MCS and its features with sufficiently high spatial and temporal resolutions. In Japan, an X-band Doppler polarimetric radar network comprising 39 radars, known as XRAIN, has been in operation since 2010 (Godo et al. 2014). Ka-band radar can detect cloud particles earlier than X-band radar. The purpose of this study is to demonstrate the predictability developing stage of a convective cloud by assimilation of XRAIN data and Ka-band radar data.

The storm-scale data assimilation system named CReSS-LETKF was developed by the authors in 2008, in which CReSS (Cloud Resolving Storm Simulator), developed by Tsuboki and Sakakibara (2002), was employed as an atmospheric model, and LETKF (Local Ensemble Transform Kalman Filter), developed by Hunt et al. (2007) and Miyoshi and Yamane (2007), was employed as a data assimilation method. The horizontal and averaged vertical resolutions were set to 1 km and 250 m, respectively. The ensemble size was set to 33 members. The radar reflectivity, Doppler velocity, and ice-water mixing ratio estimated from XRAIN were assimilated. Although x-band radar has attenuation problem, XRAIN data are corrected by KDP. And then, XRAIN compensates each other using total 39 radars network. Next, The radar reflectivity by Ka-band radar also assimilated.

In the experiment of assimilating developing period for forecasting the mature stage, the effect of assimilation of the XRAIN data lasted for more than 60 min, because the strong upward wind could be reproduced. However, continuous convective cells that were generated over small mountainous regions could not be reproduced, because the cold air inflow at middle-low levels over the mountainous regions was not predicted well in this event. Therefore, assimilation of the stratiform cloud before the initiation of the MCS was carried out, because the stratiform cloud could change the temperature in low by evaporation. Accordingly, some convective cells around the mountainous regions could be simulated by the assimilation. This study shows the assimilation of radar data provides both the direct effects and the indirect effects; the former indicates direct-reproduced rain cloud and velocity, and the latter indicate indirect-reproduced air temperature that is changed by the direct-reproduced rain cloud and velocity. The effect by data assimilation of reflectivity of Ka-band radar showed a good performance. The simulated initial stage of convective cell that was generated by the data assimilation could develop well into a tall convective cell, compared with a case of data assimilation of reflectivity by X-band radar. The reason is that forecast error covariance which were made by ensemble forecast has a high relation with cloud water rather than rain water.

Keywords: data assimilation, rainfall prediction, Ka-band radar, X-band radar