# Short-term prediction of cumulonimbus basing on upstream low-level humidification as a radar data assimilation

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Thunderstorms are induced by well-developed cumulonimbus clouds in general. To predict the activities of lightning, evolution of cumulonimbus clouds should be predicted by some techniques. However, there are some difficulties in prediction of cumulonimbus clouds associated with chaotic properties due to strong non-linearity in cloud forming processes. Short-term prediction of rainfall is performed as the precipitation Nowcast by Japan Meteorological Agency. The nowcast is based on temporal extrapolation of radar observed rainfall distribution assuming the invariance. However, the evolutions of cumulonimbus clouds are accompanied by the significantly large variations. The accuracy of the nowcast remarkably decreases with forecast time. Numerical simulations of cloud-resolving atmospheric models have a capability to predict structures and evolutions of cumulonimbus clouds. However, some problems are included in the data assimilation processes which are calculated to create initial conditions of the simulations. The data assimilation uses computational costs and takes comparably long time until the prediction is produced. In addition, detailed structure within cumulonimbus clouds are not involved in the initial condition of simulations. Thus, the author proposes a new data assimilation scheme for short-term prediction of cumulonimbus clouds, which is named as upstream low-level humidification (ULH) method. In the data assimilation, meteorological radar data are used to detect signals of cumulonimbus clouds. Here, the radar reflectivity information are not used to modify variables of rain water content. Instead, the information is translated to that of initial structure of cumulonimbus cloud which produced observed intense rainfall. In practical, areas where rainfall intensity is larger than 10 mm/h are horizontally advected toward the upstream side with 10-40 minutes. The water vapor in the lower atmosphere below the level of free convection is forced to add to be saturated by the nudging technique. The nudging coefficient is 1 minute. The ULH plays a role in the approximated adjoint calculation for time integration of four-dimensional variational data assimilation. In the installed prediction system, 3-hour forecasts are performed every 10 minutes, because the predictions should be updated with a shorter time interval due to the strong chaotic properties.
This method was applied to a heavy rainfall event observed in the Kanto Plain on September 2, 2013. The heavy rainfall caused by a few cumulonimbus clouds was well predicted by the ULH method up to forecast time of 30 minutes. The upstream advection period of 20 minutes was appropriate for more accurate predictions. The predicted cumulonimbus cloud included a large vertical vorticity that seems to have been associated with the observed tornado. The ULH was also applied to a heavy rainfall event observed at Hiroshima, Japan on August 20, 2014. A line-shaped stationary rainband was observed as a cluster of cumulonimbus clouds. The observed rainband was also roughly predicted by the ULH method. However, there were some problems for ULH method. Unobserved intense rainfall are sometimes predicted. The schemes to remove such unrealistic cumulonimbus clouds are currently developed. The ULH method have a possibility to predict cumulonimbus clouds. The possibility would be extended to predictability of lightning.

Keywords: cumulonimbus, short-term prediction, cloud-resolving atmospheric model

 