A Suggestion for Data Assimilation Method of Hydrometeor Types Estimated from the Polarimetric Radar Observation

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ABSTRACT: It is important for 0-6 hour nowcasting to provide for a high-quality initial condition in a meso-scale atmospheric model by a data assimilation of several observation data. The polarimetric radar data is expected to be assimilated into the forecast model, because the radar has a possibility of measurements of the types, the shapes, and the size distributions of hydrometeors. In this paper, an impact on rainfall prediction of the data assimilation of hydrometeor types (i.e. raindrop, graupel, snowflake, etc.) is evaluated. The observed information of hydrometeor types is estimated using the fuzzy logic algorism. As an implementation, the cloud-resolving nonhydrostatic atmospheric model, CReSS, which has detail microphysical processes, is employed as a forecast model. The local ensemble transform Kalman filter, LETKF, is used as a data assimilation method, which uses an ensemble of short-term forecasts to estimate the flow-dependent background error covariance required in data assimilation. A heavy rainfall event occurred in Okinawa in 2008 is chosen as an application. As a result, the rainfall prediction accuracy in the assimilation case of both hydrometeor types and the Doppler velocity and the radar echo is improved by a comparison of the no assimilation case. The effects on rainfall prediction of the assimilation of hydrometeor types appear in longer prediction lead time compared with the effects of the assimilation of radar echo only.

1 INTRODUCTION

It is important to estimate initial state of variables in meso-scale atmospheric model for short-term rainfall prediction. In recent years meso-scale ensemble prediction is a relatively new research field in numerical weather prediction (NWP). A major concern in ensemble prediction is to generate a limited number of initial ensemble perturbations that represent adequately errors in a high dimensional atmospheric system. The ensemble Kalman filter (EnKF) is a new method of data assimilation and generation of ensemble perturbations. EnKF uses an ensemble of short-term forecasts to estimate the flow-dependent background error covariances required in data assimilation. There have been several researches that apply EnKF to regional convective scale models using a Doppler radar data; that is radial velocity and radar reflectivity, or using precipitable water observed from GPS satellite (e.g. Snyder and Zhang 2003). Many observation data are useful for the estimation of most probable state of atmosphere. But few researches that involved polarimetric radar observation have been conducted. Polarimetric radar data will be expected to be assimilated into moso-scle atmospheric model.

It is demonstrated that polarimetric radar can retrieve raindrop size distributions, and can show promise in classifying hydrometeor (e.g. straka et al. 2000). Both information is, of course, useful on quantitative precipitation estimation (QPE). Moreover, it is a key factor for data assimilation of cloud microphysics, so an effective quantitative precipitation forecasting (QPF) will be expected in near future. However, there are two reasons that few researches that involved the data assimilation of polarimetric radar data. One is that it is theoretically-impossible that the polarimetric radar parameters cannot be constructed using only forecast model variables; that is, the observation operator of polarimetric radar does not exist. The other is that there are few observation data that validates the reasonability of the observation operator, if it can be derived under some assumptions.

In this study, the observation operator concerning hydrometeor types is developed using the campaign observation data in Okinawa. In the observation, the C-band polarimetric radar observation synchronized with the “video sonde” observation is carried out. In addition, an impact on rainfall prediction of the data assimilation of hydrometeor types (i.e. raindrop, graupel, snowflake, etc.) is evaluated.

2 OBSERVATION OPERATOR CONCERNING HYDROMETEOR TYPES

2.1 Campaign observation in Okinawa

In order to find out the relationship between the polarimetric radar data and the model variables, the campaign observation in Okinawa has been conducted in autumn 2007 and in summer 2008. Fig. 1 shows the various instruments used at the observation. Especially, the C-band polarimetric radar observation synchronized with the “video sonde” observation is carried out.

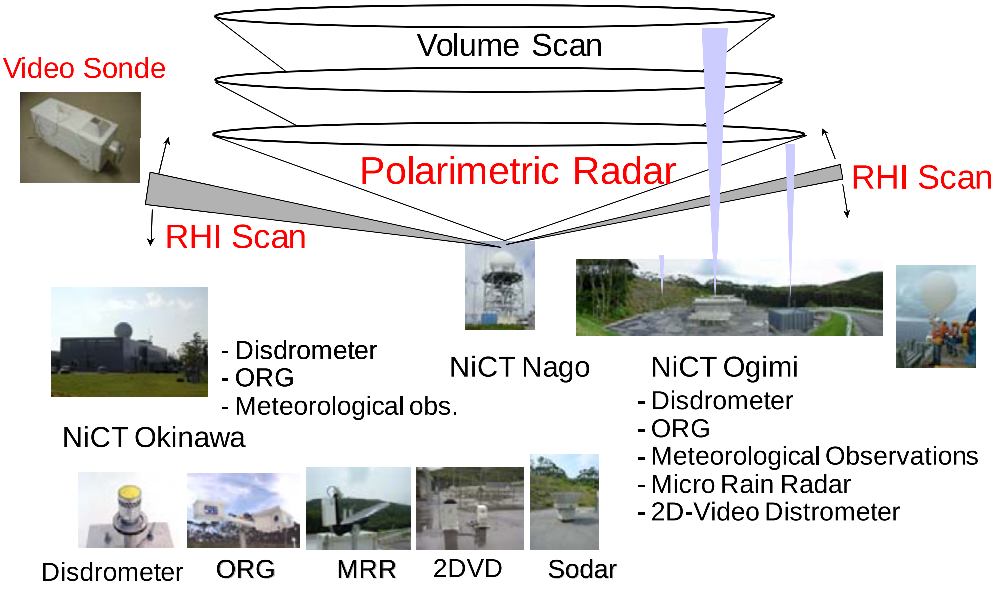

Fig. 1. Various instruments at the campaign observation in Okinawa

2.2 Hydrometeor classification

From the synchronized observation of the polarimetric radar and the video sonde, hydrometeor classification method based on fuzzy logic is developed (S. Lim et al. 2005). The hydrometeor classification method chooses four types of hydrometeors (rain, graupel, ice-crystal, and snowflake) and also can express the mixing condition of some types of hydrometeors. The degree index is determined by the following equation.

$$Q_j = \mu_j^{MLH}(h) \times \left(\mu_j^{Z_{HH}}(Z_{HH}) + \mu_j^{Z_{DR}}(Z_{DR}) + \mu_j^{\rho_{HV}}(\rho_{HV}) + \mu_j^{K_{DP}}(K_{DP})\right) \qquad (1)$$

where *j*=rain, graupel, ice crystal snowflake. Fig. 2 shows the result of hydrometeor classification. It can be seen that the mixing condition of two types is corresponding to the video sonde observation.

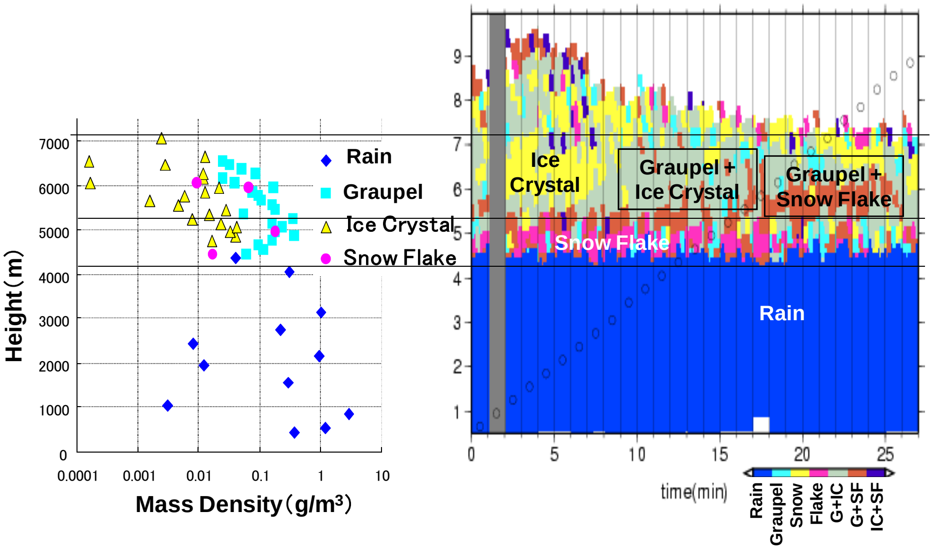

Fig. 2. Vertical profile of hydrometeor classification using polarimetric parameters (right). Vertical profile of mass density of each hydometeors by the video sonde ovservation (left).

2.3 Development of observation operator concerning hydrometeor types

In this section, a relationship between the degree indexes in equation (1) observed by the polarimetric radar and the number density of each hydrometeor observed by the video sonde is detected. The degree indexes *Q* is converted to *Q'* using quation (2) so that the defference can clear up.

$$Q'_i = Q_i - \left(\max\left(Q_{\mathrm{graupel}}, Q_{\mathrm{ice\ crystal}}, Q_{\mathrm{snowflake}}\right) - 0.100\right) \qquad (i = \text{graupel, ice crystal, snowflake}) \qquad (2)$$

Moreover, as the video sonde observation of the number density is underestimated because of its capture rate, the abundance ratio of graupel is derived by equation (3).

$$R_{\mathrm{graupel}} = \frac{Q'_{graupel}}{Q'_{graupel} + Q'_{icecrystal} + Q'_{snowflake}} \qquad (3)$$

Fig. 3 shows the relationship between the number density ratio of graupel by video sonde observation and R_{graupel} estimated by the polarimetric parameter.

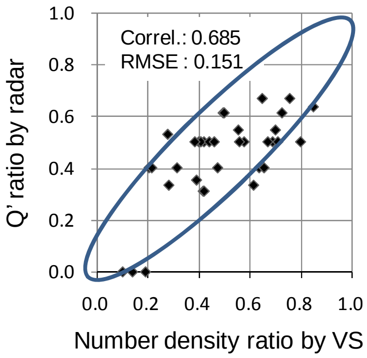

Fig. 3. The relationship between number density ratio by video sonde observation and R_{graupel} estimated by the polarimetric parameter

3 DATA ASSIMILATION OF HYDROMETEOR TYPES

3.1 CReSS-LETKF

In this chapter, an impact on rainfall prediction of the data assimilation of hydrometeor types using the relationship in 2.3 section is evaluated. The data assimilation system called CReSS-LETKF (Yamaguchi and Nakakita, 2008) is used. The local ensemble transform Kalman filter (LETKF) technique developed by Hunt (2007), one of EnKF techniques (square root filter techniques in a narrow sense), is applied to the non-hydrostatic atmospheric model named Cloud Resolving Storm Simulator (CReSS, Tsuboki and Sakakibara 2002).

Four experiments are conducted. The first experiment is to assimilate Doppler velocity, the second is to assimilate both Doppler velocity and radar intensity, the third experiment is to assimilate the hydrometeor types in addition to the second experiment. The last experiment is not to assimilate any observation data.

For case study, the rainfall event occurred on June 3 in Okinawa is chosen.

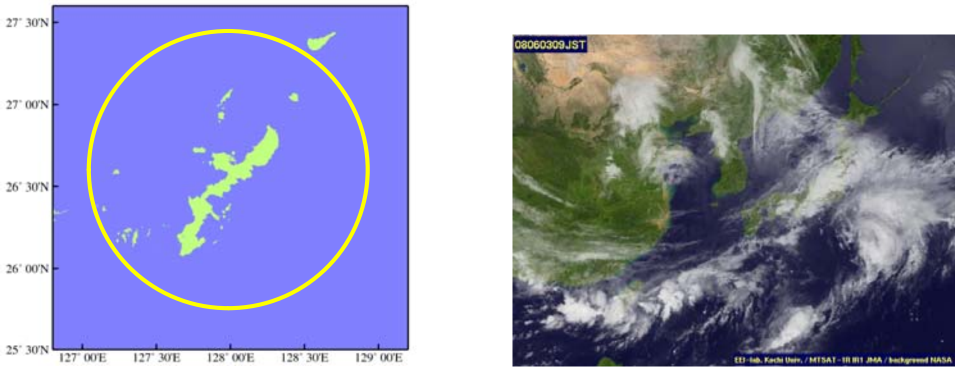

Fig. 4. The experiment domain (left). The yellow circle indicates the maximum radius of the palarimetric radar, COBRA. The cloud image by the satellite observation. Citation from http://weather.is.kochi-u.ac.jp/

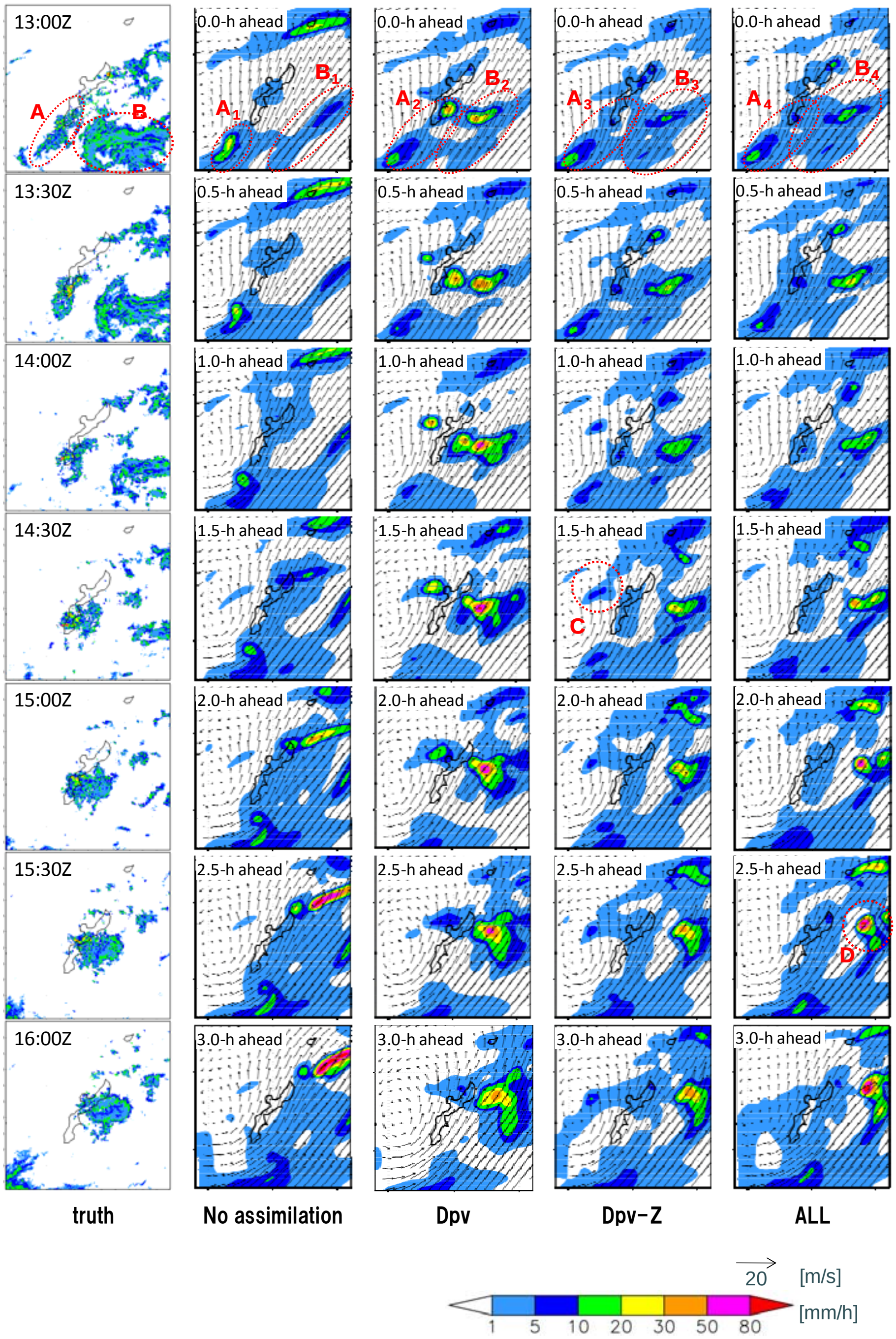

Fig. 5. The forecast results of four experiments and radar observation. The color indicates the rainfall rate at the ground and the vector indicates the horizontal wind at the height of 1.5 km.

3.2 Results

Fig. 5 shows the forecast results on each experiment. It can be seen that the precipitation area in all assimilation cases is corrected compared with the no assimilation case at 13:00 that represent the end of the assimilation. However, the effect on rainfall prediction by the assimilation of hydrometeor types is little, because the amount of the hydrometeor is rarely corrected as the hydrometeor types are collected by the assimilation. We are now trying to develop the assimilation method of the amount of each hydrometeor. This study shows the novel idea of data assimilation method using the polarimetric radar observation.

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