Data assimilation using GPM/DPR at JMA

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1. Introduction

The global precipitation measurement (GPM) core satellite carries a dual-frequency precipitation radar (DPR) incorporating Ku-band precipitation radar (KuPR) and Ka-band precipitation radar (KaPR). The DPR instrument was developed by the Japan Aerospace Exploration Agency (JAXA) in cooperation with the National Institute of Information and Communications Technology (NICT), and observes vertical profiles of reflectivity in the mid-latitude region between 65°S and 65°N. As radar reflectivity profiles are commonly observed on land but rarely at sea, hydrometeor information included in these reflectivity data is very valuable for forecast verification and data assimilation relating to mesoscale phenomena. In evaluation of the impacts of DRP data assimilation to create the initial conditions of JMA's mesoscale model (MSM) with a 5-km horizontal resolution, precipitation forecast improvement was observed despite the narrow swath width of KuPR and KaPR (250 and 150 km, respectively) in comparison to those of other orbit satellite observations. The Japan Meteorological Agency (JMA) began using DPR data in its operational mesoscale NWP system in March 2015. This document outlines the method of DPR assimilation and related impacts.

2. Method

In DPR assimilation, relative humidity (RH) data retrieved from the DPR reflectivity profile using Bayesian theory are assimilated on the basis of 4DVAR (Ikuta, 2014). This method, known as 1D+4DVAR, is also used for assimilation of ground-based weather radar (Ikuta and Honda, 2011). For this assimilation, a new space-borne radar simulator was developed and the previous RH retrieval method used was upgraded.

First, KuPR reflectivity ($\mathrm{Z_{Ku}}$) and KaPR reflectivity ($\mathrm{Z_{Ka}}$) were simulated from MSM outputs using the new space-borne radar simulator. As all hydrometeors are assumed to be spherical in the MSM, the radar cross section is calculated using the Lorenz-Mie theory. To reduce the computation time of the simulator, a Mie-scattering table was formulated in advance.

Second, RH data to be assimilated are retrieved from $\mathrm{Z_{Ku}}$ and $\mathrm{Z_{Ka}}$ values based on the Bayesian theorem using the predetermined relationship between simulated values of $\mathrm{Z_{Ku}}$ and $\mathrm{Z_{Ka}}$ and RH for the first guess. As simulated reflectivity from MSM outputs is known to have biases (Eito and Aonashi, 2009), adaptive bias correction is assimilated into the retrieval method via the removal of expected values of observed reflectivity minus simulated reflectivity as a bias from observed reflectivity in the equation used for the prior probability density function. Despite the assimilation of such bias-corrected data, assimilation of ice phase data cancels the water-vapor bias in the upper atmosphere caused by the model's characteristics but reduces the weak precipitation frequency toward the negative bias. Accordingly, only the liquid phase of DPR is currently used in data assimilation.

3. Performance evaluation

An experiment to determine the effects of DPR assimilation was performed in a framework similar to that of the operational mesoscale NWP system. Here, the regular analysis-forecast cycle experiment is referred to as CNTL, and that with DPR assimilation is referred to as TEST. An example of the impact of DPR was observed for a heavy rainfall event (over 160 mm/3 h) during the period from 8 – 10 September 2015. DPR was assimilated at the initial times of 15 UTC on 7 September and 00 UTC on 8 September (Fig. 1) before this severe weather event. In the mesoscale NWP system, the analysis and forecast cycle gains efficiencies from DPR assimilation with each initial condition. As a result, the precipitation forecast with a lead time of 33 hours (Fig. 2) was improved in the TEST run. In addition, even though fewer DPR data are assimilated and the coverage area of DPR is smaller than those of other satellites, statistical evaluation showed improvement at over 10 mm/3 h (Fig. 3). The statistical period examined was from 2 August 2015 to 10 September 2015. The impact in winter was low because ice-phase data were not used. Utilization of such data is key to improving snowfall forecasts in winter.

References

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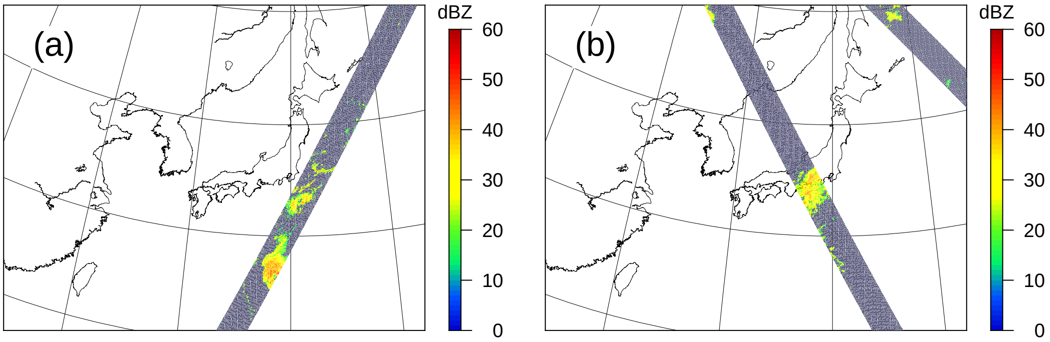

Figure 1. KuPR observation at an altitude of 3,000 m in an assimilation window with the initial times of (a) 15 UTC on 7 September and (b) 00 UTC on 8 September 2015.

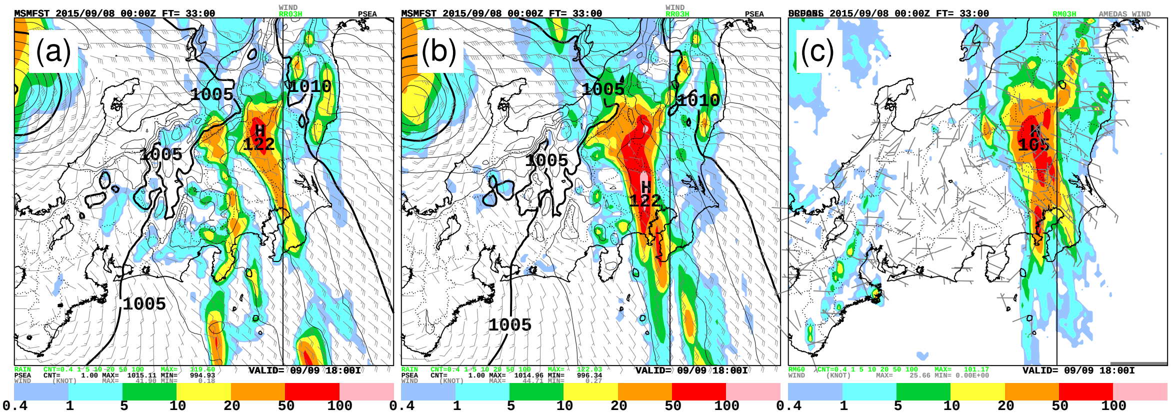

Figure 2. Cumulative three-hour precipitation, surface wind and surface pressure forecasts of (a) CNTL and (b) TEST with a lead time of 33 hours and an initial time of 00 UTC on 8 September 2015, and (c) radar analysis and AMeDAS wind at 03 UTC on 9 September 2015.

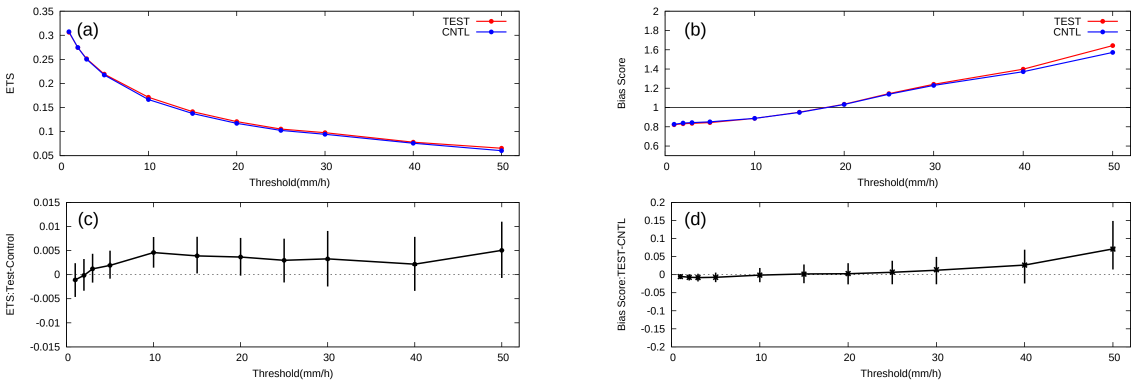

Figure 3. (a) Equitable threat scores (ETS) and (b) bias scores for cumulative three-hour precipitation against radar analysis from 2 August to 10 September 2015. (c) TEST-CNTL of ETS and (d) that of bias score. The error bar represents the 95 % confidence interval.