Preliminary results of assimilation of reflectivities of space-borne precipitation radars

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1. Background

Space-borne precipitation radars, such as precipitation radar (PR) on the Tropical Rainfall Measurement Mission (TRMM) satellite and dual-frequency precipitation radar (DPR) on the Global Precipitation Measurement (GPM) Core satellite, measure accurate vertical precipitation profiles over both land and sea. This information is valuable for numerical weather prediction (NWP) because it complements ground-based radars and microwave imagers (MWIs). Aonashi and Eito (2011) have developed an ensemble-based variational (EnVA) scheme using a cloud-resolving model (CRM) and demonstrated that assimilation of precipitation-affected brightness temperature (BT) from MWIs improved precipitation forecasts. We improved EnVA by incorporating a radar simulator to assimilate radar reflectivity factors (Ze) and developed pre-processing for Ze. Preliminary results of TRMM/PR Ze assimilation are presented in this paper.

2. Model comparison

To understand the characteristics of models and Ze observations, we compared them in the attenuation-corrected Ze space. We employed the non-hydrostatic model (NHM) of the Japan Meteorological Agency (JMA) (JMA-NHM; Saito et al. 2004) as a CRM and the multi-satellite simulator called Joint-simulator (Hashino et al. 2013) as a radar simulator. The JMA-NHM in this study adopts a bulk microphysical scheme with two-moments for three ice species and is run with 5 km horizontal resolution in a region of 401 × 401 grids.

Figure 1 is a contoured frequency by altitude diagram (CFAD) showing a comparison between observation and the JMA-NHM ensemble forecast mean, which is used as the first-guess (FG) of data assimilation, for typhoon Conson at 22 UTC, June 9, 2004. It shows that the JMA-NHM significantly overestimates strong Ze from ice particles above the melting layer at approximately 5 km. This outcome is attributed to overestimating the population of large ice particles. For liquid–particle scattering, the frequency peak is located at modest Ze from 24 to 30 dBZ for observation and at lower Ze for FG. This inconsistency is related to displacement error of the rain band in the model simulation, as shown in Fig. 2, where the rain-mixing ratio (Qr) is overestimated in Area A and underestimated in Area B.

3. Assimilation of TRMM/PR Ze

We included the Joint-simulator as an observation operator for Ze in EnVA. For the initial implementation of assimilating Ze, we developed conservative quality-control (QC) procedures. Using these procedures, we excluded those observations in and above the melting layer, those affected by ground clutter, those having larger departure from FG, those with isolated rain signal in the vertical profile, or those with both observed and FG values less than the minimum value (17 dBZ). Furthermore, observations are thinned at every other angle bin and scan pixel for more optimal minimization and to reduce computational burdens.

We carried out three assimilation experiments to examine Ze assimilation performance in EnVA: (1) the “PRonly” experiment, in which PR Ze alone is assimilated; (2) the “TMIonly” experiment, in which TB of four vertical polarized channels at 19, 21, 37, and 85 GHz from the TRMM Microwave Imager (TMI) is assimilated, as in Aonashi and Eito (2011), and (3) the “PR+TMI” experiment, in which both PR Ze and TMI TB are assimilated. Figure 3 shows the analysis and its increment (analysis minus FG) for Qr at 2.5 km. All of these experiments successfully correct Qr to reduce the difference between observation and FG, as shown in Figs. 3 (b, d and f). The PRonly experiment, however, generates an analysis increment in a very limited area that corresponds to the PR observation coverage, resulting in an unnatural structure of the analyzed typhoon (Fig. 3 (a)). Both the TMIonly and the TMI+PR experiments produce wider analysis increments, as shown in Figs. 3 (d and f), because TMI has

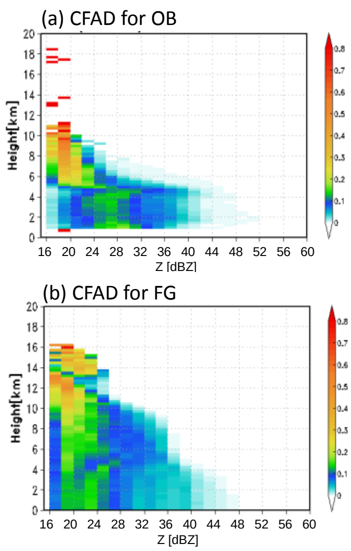

Fig. 1. CFAD of (a) observation (OB) of TRMM/PR and (b) first-guess (FG) from 7-hour ensemble forecast mean of JMA-NHM initialized at 15 UTC on June 9, 2004.

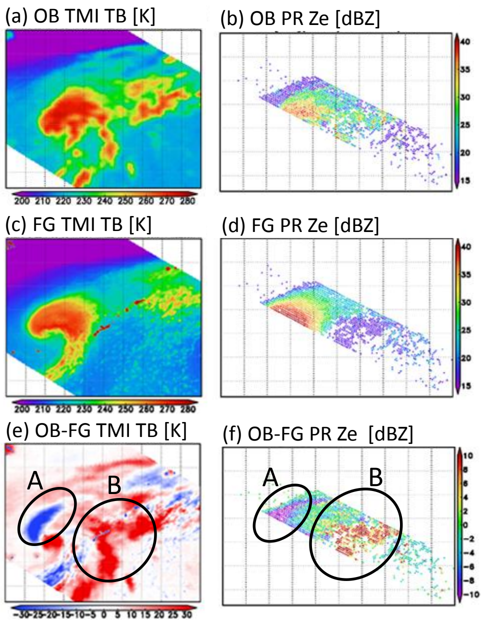

Fig. 2. (a, c, and e) observation (OB), first-guess (FG), and their difference of TB (Kelvin) of vertically polarized channel at 19 GHz (TB19V) from TMI. (b, d, and e) as in (a, c, and e) but for PR Ze (dBZ) at 2.5 km.

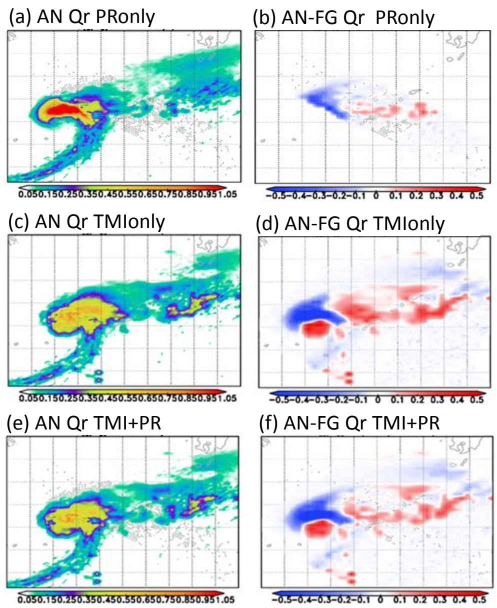

Fig. 3. Analyzed Qr (g/kg) at 2.5 km (AN) and its departure from first-guess (AN-FG) for three experiments.

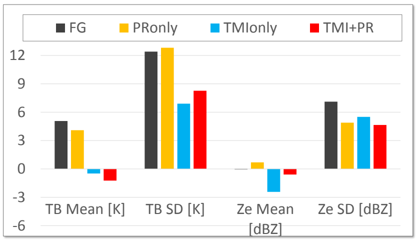

Fig. 4. Mean and standard deviation of OB-FG and OB-AN for three experiments with respect to TB19V and PR Ze.

a much wider scan-swath width of 878 km than the PR scan-swath width of 240 km. The TMI+PR experiment creates a slightly finer analysis increment than the TMIonly experiment because of smaller PR pixels.

The quality of the analysis with respect to the agreement with observations of TMI TB and PR Ze is summarized in Fig. 4. Large mean and standard deviations in TB for the PRonly experiment suggest that PR mainly corrects Qr to draw analysis to PR but has little impact on large-scale variables related to TB, such as humidity and temperature. This is confirmed by the analysis increment of these variables (not shown) and is explained by the fact that in EnVA control variables related to Qr have small correlation with the large-scale variables. In contrast, the analyses for TMIonly and TMI+PR experiments are in better agreement with TB and comparably fit Ze. A relatively large negative mean difference of Ze in the TMIonly experiment indicates that the TMI+PR experiment makes a more balanced analysis than the TMIonly experiment.

4. Summary and Plans

We compared observed Ze and its model counterpart and found several deficiencies in the cloud microphysics in the JMA-NHM. Based on these findings, we developed QC procedures for Ze in EnVA. Assimilation experiments showed the importance of synergetic use of PR and TMI and the possibility to better analyze Qr. To further evaluate impacts of space-borne radars, we plan to make forecasts from the analysis made by assimilating Ze. Assimilation of DPR Ze is also under development.

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