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CURRENT STATUS OF THE DUAL-FREQUENCY PRECIPITATION RADAR (DPR) LEVEL-2 STANDARD ALGORITHM

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1. INTRODUCTION

The launch of the core satellite of the Global Precipitation Measurement (GPM) mission with the Dual-frequency Precipitation Radar (DPR) on is scheduled for July 2013. DPR consists of KuPR, frequency of which is similar to the Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR; 13.8GHz while 13.6GHz is used for KuPR), and KaPR (35.5GHz). As KuPR and KaPR are different from each other in terms of scanning geometry (Fig. 1), there are three types of pixels: observed by KuPR only (indicated by blue: type-A), observed by KaPR only (indicated by red: type-B), and observed by KuPR and KaPR simultaneously (indicated by purple: type-C).

The DPR standard algorithm Level-2 (L2) consists of three algorithms: KuPR algorithm which can use KuPR measurement only and is applied for type-A and type-C pixels, KaPR algorithm which can use KaPR measurement only and is applied for type-B and type-C pixels, and dual-frequency algorithm which can use both KuPR and KaPR measurement and is applied for type-A, type-B, and type-C pixels. Later in this paper, dual-frequency algorithm is explained for application to type-C pixels.

The vertical profiles of echo power given by the DPR standard algorithm Level-1 (L1) are inputted to L2, and the vertical profiles of DSD, precipitation rates, and other variables related to precipitation are outputted by L2. Figure 2 shows the framework of L2. Please note that this framework is

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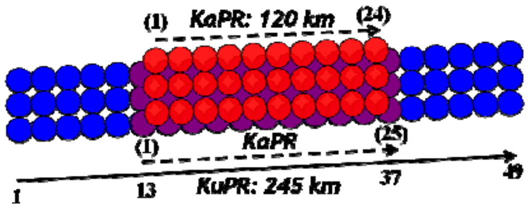

Fig. 1 The scanning geometry of KuPR and KaPR.

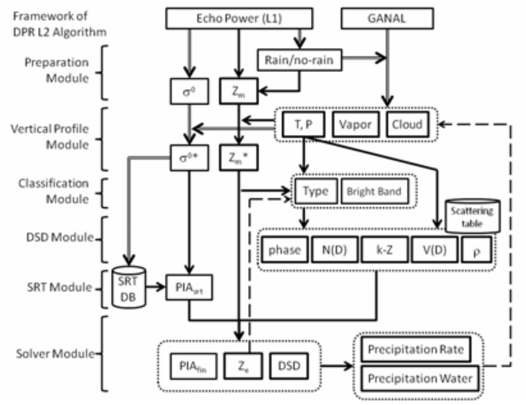

Fig. 2 A flow chart of the DPR L2 algorithm.

common to KuPR, KaPR, and dual-frequency algorithms. L2 is divided into 6 sub modules. Preparation module is for rain/no-rain classification, clutter detection, calculation of radar reflectivity factors (Z_m's) and surface backscattering cross sections (σ^0). Vertical Profile module is to derive the vertical profiles of atmospheric variables (e.g. air temperature) from GANAL, and to correct for attenuation by non-precipitation particles (clouds, water vapor, and oxygen). Classification module is for precipitation type classification and bright band detection. DSD module is to assume characteristics of precipitation particles and to set scattering tables. SRT module is to apply Surface Reference Technique (SRT) for the first guess of Path Integrated Attenuation (PIA). Solver module is to correct attenuation for precipitation particles and to retrieve DSD and calculate precipitation rates and other variables.

L2 is developed by the authors, delegated by JAXA and NASA. By this autumn, a baseline code is produced with some basic and important functions. By next autumn, functions are added and the baseline code will be modified to an at-launch code, which should be close to the first version of the operation code.

Considering that DPR is a successor to PR, KuPR algorithm is developed based on the TRMM/PR standard algorithm (Iguchi et al. 2009). At the same time, by taking the advantage of additional measurement at Ka-band, dual-frequency algorithm should be better than single-frequency algorithms. For example, SRT module estimates the difference of PIAs between the two frequencies (dPIA; Meneghini et al. 2011). This method is called Dual-frequency SRT (DSRT) and the estimates of dPIA are expected to be more accurate than those of PIA as the biased caused by the changes in surface conditions are largely cancelled between KuPR and KaPR.

For solver module, a new retrieval method (called HB-DFR method) is developed and the unique code is applied both for single-frequency and dual-frequency algorithms. In the next section, HB-DFR method is introduced.

2. HB-DFR METHOD

In the TRMM/PR standard algorithm, a hybrid method with Hitschfeld-Bordan (HB) method and SRT is applied. In HB method, by assuming relations between specific attenuation k and radar reflectivity factor Z_e as power law ($k=\alpha Z_e^{\beta}$), the vertical profile of measured radar reflectivity factor $Z_m(r)$ is corrected to $Z_e(r)$, where r is range distance. The parameter α can be range dependent, but β should be fixed. By integrating k along the range from the radar to the surface, PIA is calculated in HB method, but this value is generally different from PIA estimate by SRT. In the hybrid method, α is adjusted by multiplying a range-independent constant ε ($\alpha(r)=\varepsilon\alpha_0(r)$; $\alpha_0(r)$ is an initial estimate). ε is determined based on a-priori probability of ε and the reliability of PIA estimates by SRT.

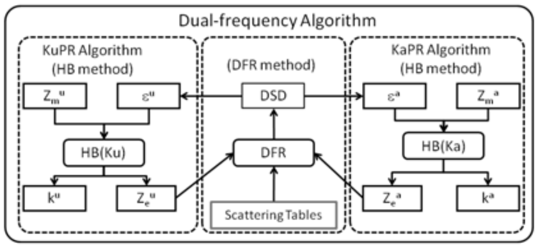

Fig. 3 The framework for HB-DFR method in the baseline code.

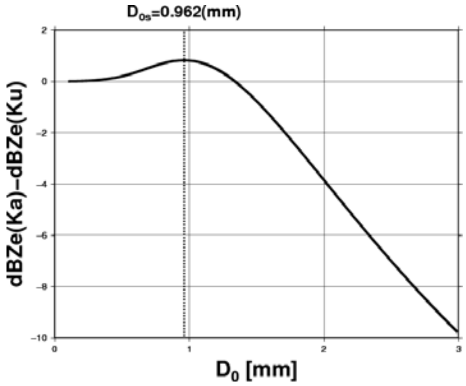

Fig. 4 DFR as a function of D_0 (rain, 0 degree C, Gamma distribution with μ=3)

The hybrid method will be incorporated in at-launch codes of KuPR algorithm and KaPR algorithm, but HB method is applied in their baseline codes. HB-DFR method is applied in baseline code of dual-frequency algorithm (Fig. 3). The left part of this figure is the same as KuPR algorithm, the right part is the same as KaPR algorithm, and the middle part is special to dual-frequency algorithm. In the middle part, for each range bin, Dual-Frequency Ratio (DFR) is calculated for Z_e's of KuPR and KaPR estimated by HB methods. In this study, DFR is defined as Z_e(Ka) minus Z_e(Ku) in decibels. For liquid spherical particles with temperature of 0 degree C, if DSD is parameterized by a Gamma distribution function with D_0 and N_0 (μ=3), relation between DFR and D_0 is given in Fig. 4. There is a famous problem that multiple solutions exist if DFR is positive. Usually, D_0 is limited to be larger than D_{0s}, where DFR takes the maximum. Once DSD is obtained, k and Z_e are calculated for each range bin and at each frequency, and ε can be recalculated (this process is called DFR metrhod). By iterating HB and DFR methods, ε is updated.

The HB-DFR method is tested with a simple simulation dataset based on the TRMM/PR standard product. The simulation dataset includes the vertical profiles of Z_m's at the two frequencies, which are exactly calculated based on DSD information given and assumed in the TRMM/PR standard algorithm. No measurement errors in Z_m's and no clutter and noise effects are considered. Characteristics of precipitation particles (DSD parameterization, falling velocity, scattering tables, and so on) are properly assumed. Under the ideal condition, HB-DFR method is applied for one-month simulation dataset. The precipitation rates at the lowest range bin are evaluated as summarized in Fig. 5. In case of medium precipitation (1-10 mm/h), the accuracy is satisfactory. But in the case of heavy precipitation (over 10 mm/h), severe underestimation are seen unless the storm height is low. Slight negative bias is seen in the case of light precipitation (under 1 mm/h).

Errors are inherent in the dual-frequency retrieval. Problems to retrieve two DSD parameters from dual-frequency Z_m's often have multiple solutions (Seto and Iguchi 2011). In this method, a solution with weaker precipitation rate is favored to be selected, which results in underestimation for heavy precipitation events. In DFR method, D_0 is limited to be larger than D_{0s}, and it results in underestimation of light precipitation, of which D_0 is often smaller than D_{0s}.

3. TOWARD AT-LAUNCH CODE

Each sub module should be improved toward at-launch code. In solver module, SRT are incorporated into the retrieval method (HB-SRT-DFR method). The a-priori probability of ε, reliability of PIA by SRT, and reliability of DSD estimates by DFR are considered to optimize ε. The retrieval method is required to be robust against random errors in Z_m's and inappropriate setting of precipitation characteristics, and is also required to be flexible to estimate the variation of ε.

The dual-frequency algorithm is expected to show seasonal and regional variations in DSD through ε. Successful results of DSD variations may be useful for ground-based conventional radars. Moreover, the parameter ε can be transferred to type-A and type-B pixels.

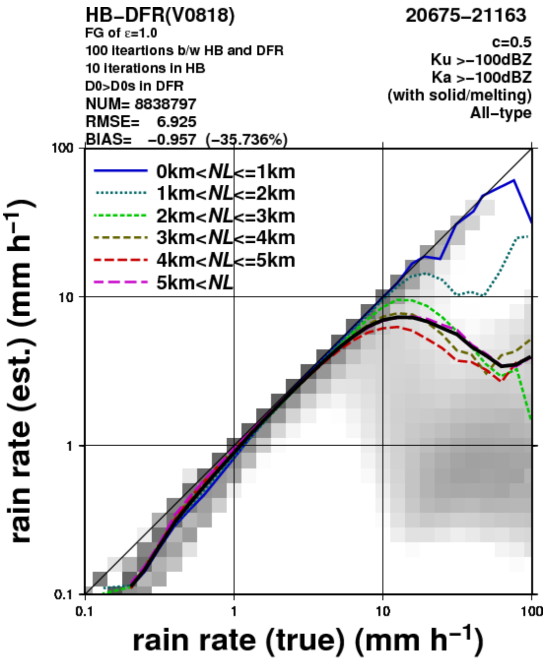

Fig. 5 Evaluation of the HB-DFR method applied to the simulation dataset.

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