History and future plan about the solver module of the DPR standard algorithm

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While the Dual-frequency Precipitation Radar (DPR) consists of KuPR (13.6GHz) and KaPR (35.5GHz), two single-frequency algorithms and one dual-frequency algorithm are developed as DPR level-2 standard algorithm (DPR-L2). The main purpose of DPR-L2 algorithm is to output the profile of precipitation rates along the beam. For the purpose, many processes such as rain/no-rain judgement, main- and side-lobe clutter rejection, attenuation correction for non-precipitating particles, precipitation type classification, surface reference technique (SRT) and assumption on drop size distribution (DSD) are required, and they are assigned to sub modules (preparation, vertical profile, classification, SRT and DSD modules). Finally, solver module corrects attenuation for precipitating particles and estimate the DSD parameters and precipitation rates at each range bin. Here, a brief history of the solver module from version 03 (V03; the earliest version in operation) to version 06 (V06; currently operated) is presented, then possible improvement for the next version (V07) is discussed.

Major inputs to the solver module is Zm (attenuation corrected for non-precipitating particles) at each range bin between the clutter free bottom to the storm top and the path integrated attenuation (PIA). If the number of range bin with Zm is N, the number of measurements are 2N+2 in case of dual-frequency algorithm and N+1 in case of single-frequency algorithm. To assume that DSD should follow the two-parameter gamma function, at least 2N measurements are required. In the single-frequency algorithm, as the number of measurements is smaller than 2N, assumptions on DSD are necessary. On the other hand, in the dual-frequency algorithm, as the number of measurements is larger than 2N, it is possible to estimate DSD without additional assumptions.

In V03, k-Ze relation is used for single-frequency algorithm as well as in the TRMM PR standard algorithm, where k is specific attenuation (per distance) and Ze is effective radar reflectivity factor. As k-Ze relation has an adjustment factor epsilon and epsilon is fixed along the beam, the number of unknown parameters is N+1 and is equal to the number of measurements. In the dual-frequency algorithm, epsilon can be variable by range bins. The estimation method is introduced in Seto and Iguchi (2015, JTECH).

In V04, R-Dm relation is used instead of k-Ze relation, where Dm is mass-weighted mean drop size. As k and Ze are frequency dependent, different equation is used for KuPR algorithm and KaPR algorithm in V03, then they are not perfectly agreed. As R and Dm are not dependent on the frequency, one equation can be used commonly for KuPR algorithm, KaPR algorithm and the dual-frequency algorithm. R-Dm relation also has an adjustment factor epsilon, which is basically same as that of V03 and PR algorithm. Even in the dual-frequency algorithm, epsilon is fixed and the number of unknowns is N+1. The estimation method has been changed for the dual-frequency algorithm because the solution is sometimes unstable in V03. In the dual-frequency algorithm of V04, Zm of KuPR is mainly used and Zm of KaPR is not mainly used as the latter is subject to strong attenuation and/or multiple scattering. The difference of PIA between KuPR and KaPR is called dPIA and is used to adjust epsilon. So, the number of measurements used in the dual-frequency algorithm of KaPR is N+1. Zm's of KaPR are used to adjust epsilon too. In V04, both KuPR algorithm and the dual-frequency algorithm mainly use KuPR's Zm, but the adjustment of epsilon is different by KuPR algorithm and the dual-frequency algorithm. Because of this, estimated precipitation rates by the two algorithms are quite different.

In V05, to compensate the difference of precipitation rates between the two algorithms, a-priori probability density function of epsilon is modified for single-frequency algorithm. For weak precipitation,

epsilon is difficult to be adjusted by SRT in single-frequency algorithm (particularly KuPR algorithm), while it is adjusted by the use of Zm's of KaPR in the dual-frequency algorithm. The statistics of epsilon is calculated from the test products of dual-frequency algorithm and a-priori pdf is determined for 5 by 5 degree grid and for every month (called DSD database).
V06 is a minor modification of V05. The use of SRT is corrected to avoid erroneously heavy precipitation over calm ocean surface. The products of V06 is evaluated by using rain gauges over Japan (Seto, 2019, IGARSS). Precipitation rates of KuPR algorithm is smaller than rain gauge measurements by about 20 %, while those of the dual-frequency algorithm is different from rain gauge measurements only by several percent.
For V07, some major improvements are planned. One is about non-uniform beam filling (NUBF) correction. NUBF correction is introduced from V04 (Seto et al. 2015, IGARSS), where the coefficient of variation (CV) of R is estimated based on the fractal theory. CV is limited up to 0.25 to avoid overcorrection. This can be a reason of underestimation in KuPR algorithm. Another is about DSD database. Disdrometer measurements should be used to validate and improve DSD database. The other is about fixed epsilon along the beam. To estimate epsilon at each range bin is quite difficult in the operation algorithm, but two epsilons for liquid part and solid part may be feasible. Considering the reliability of Zm's (particularly of KaPR), the degree of freedom for epsilon should be changed. We hope to make estimates of precipitation rate and related variable (such as Ze and Dm) more accurate in V07.

Keywords: DPR, DSD, GPM