P16.11 A NEW SCHEME TO ESTIMATE RAIN RATE FROM AN S-BAND POLARIMETRIC RADAR, IMMUNE WITH RESPECT TO DSD VARIABILITY AND RADAR CALIBRATION ERROR

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1. INTRODUCTION

S-band radars offer the advantage of providing rainfall rate estimation quite directly, especially from Z-R relation, since attenuation effects are negligible. However, the natural variability of the rain is another source of error that may be quite important. Such variability is described fairly well by the normalized intercept parameter N_0^*, that should be accounted for in rain estimators, but cannot be determined in conventional algorithms. Using multi-parameter relationships allowed by polarimetric techniques is an opportunity to remove this effect, but it is subject to calibration error.

The rain profiling algorithm ZPHI (Testud et al., 2000), initially developed to overcome the problem of attenuation for operational C- and X-band polarimetric radars, is proposed to solve the natural rain variability effect for S-band polarimetric radars. As a matter of fact, N_0^* is one of the key parameters retrieved by ZPHI. The rainfall rate is then expressed as a function of N_0^* and of the specific attenuation A, but is still subject to calibration error. The retrieved rain rate is statistically compared with a second estimator, in order to determine the calibration error with a 0.1 dB accuracy. The delivered rain rate is then immune to both rain variability and calibration error. ZPHI has been validated from C-band radar data (Le Bouar et al., 2001).

In the present paper, first results from the application of ZPHI with S-band polarimetric radar data are shown. The data used were gathered by the S-band polarimetric radar operating at the TRMM ground validation site of Kwajalein.

2. ALGORITHM ZPHI

Algorithm ZPHI is a rain profiling algorithm, i.e. at a given point observed by the radar, it estimates the rainfall rate not from this single point only, but from the whole profile of the measured reflectivity between two selected bounds r_a and r_b. It is based on Hitschfeld and Bordan (1954)'s formulation and, for stabilizing it, requires the differential phase shift difference $\Delta\Phi = [\Phi_{DP}(r_b) - \Phi_{DP}(r_a)]$.

The inverse model of ZPHI specifies some "universal" relations between parameters that are normalized by N_0^*, such as $A/N_0^* = a\,[Z/N_0^*]^b$, where a and b depend on temperature only.

The basic hypothesis used in the process is the constancy of N_0^* between bound r_a and bound r_b. This hypothesis is reasonable when the interval is covering an unique kind of rain. Consequently, ZPHI operates a systematic segmentation along each beam, in order to ensure an optimal variability of N_0^* (constant in each interval, but variable along the beam if segmented into several intervals).

The primary output parameters are A (dB km^{-1}), N_0^* (m^{-4}), and the rainfall rate R (mm h^{-1}), hereafter denoted R_{ZPHI}. ZPHI may also provide a retrieved K_{DP}, since it uses an A-K_{DP} relation in its inverse model. R_{ZPHI}, resulting from A and N_0^*, could then be considered as a combination of K_{DP} and N_0^* through the A-K_{DP} relation.

An example of application to the S-band radar data is shown in Figure 1: From the reflectivity profile (top panel) and the Φ_{DP} measurements at some selected bounds (marked by the (✻) symbols in the middle panel), the profile of A is retrieved and N_0^* is determined for each interval (values in the middle panel). The rainfall rate profile is then deduced (bottom panel). As shown in the middle panel, the algorithm also acts as a physical interpolator between $\Phi_{DP}(r_a)$ and $\Phi_{DP}(r_b)$, with a reduced random error.

3. SENSITIVITY TO CALIBRATION ERROR

The only parameter that makes R_{ZPHI} sensitive to calibration error is N_0^*. Indeed, if C is the radar calibration error (in dB), $\log_{10}(N_0^*)$ is shifted by -0.1 C [b/(1-b)] (see Le Bouar et al., 2001 for details). To overcome such sensitivity, R_{ZPHI} is compared with a second R estimate. The latter, also produced by ZPHI, uses the differential reflectivity Z_{DR} and the retrieved A, and is immune to calibration error. ZPHI is thus capable to estimate the absolute radar calibration error.

4. K_{DP} RETRIEVAL

Since it is not measured directly, K_{DP} has to be derived from Φ_{DP}, but estimating it is uneasy in practice because of random phases errors. One solution for this problem is to operate with a sufficiently long dwell time. Such solution is not satisfactory for operational use. A second conventional solution consists of involving a certain range interval (for smoothed or weighted finite difference, or for regression approaches), that may decay the spatial resolution.

With ZPHI, K_{DP} is not directly retrieved from the "local"

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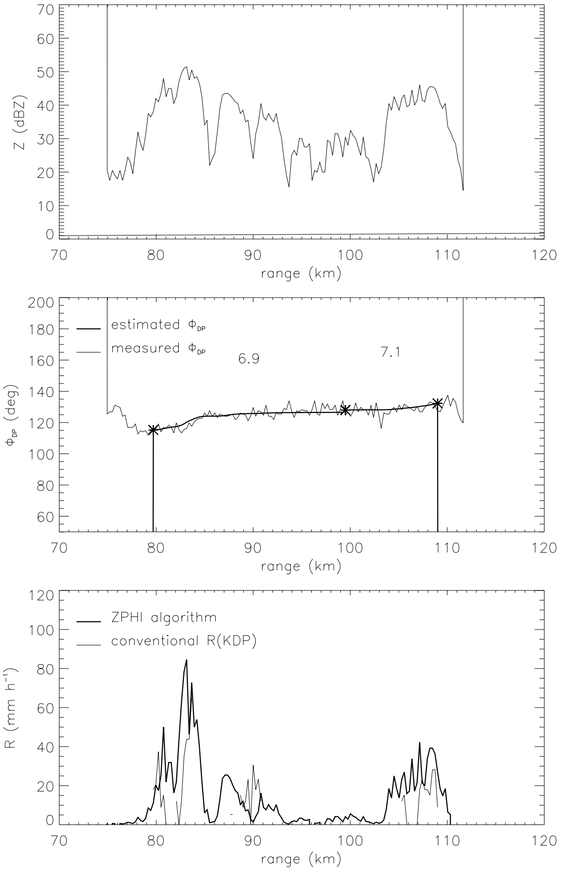

Figure 1: Along-beam profiles at 0.9° elevation, on 07/30/2000, 2:52. Top : measured reflectivity Z. Middle : Measured differential phase shift Φ_{DP} (thin line) and retrieved one (bold line) ; the numbers are $\log_{10}$ of N_0^*, and (✻) symbol are bounds of segmentation of the treatment. Bottom : Rainfall rate retrieved from a conventional K_{DP} (thin line) and from ZPHI (bold line). The conventional K_{DP} has been obtained by regression approach over 10 range gates, i.e. 2.64 km length.

lot of measured $\Phi_{DP}(r)$, but is in part deduced from the information given by $\Delta\Phi$.

The results can be qualified in Fig. 2 ((●) symbol), where K_{DP}/Z is plotted against Z_{DR} for a whole PPI exploration. The purpose of dividing K_{DP} by Z is to make the diagram completely independent of N_0^*, and then of the DSD variability. The scatter of this plot is relatively reduced, and allows to establish easily an empirical relation between K_{DP}/Z and Z_{DR}. With a conventional K_{DP}, for instance computed in a regression approach ((□) symbol in Fig. 2), the obtained diagram is much more scattered, and prevent any relation to be established clearly.

5. CONCLUSION

Some very first application of ZPHI on S-band radar data has been presented in this paper. The results show that in S-band the specific attenuation profile can be retrieved and lead to the rainfall profile, even if the integrated path-attenuation is negligible. A particular interest of using ZPHI for S-band data lies in its capability to determine the intercept parameter N_0^* (and then to account for rain variability), and to provide a new K_{DP} estimate affected by a reduced random error.

In the next future, such application will be extended to a wider set of radar data. A validation study will also be performed, taking advantage of the gauge network deployed around the radar in Kwajalein.

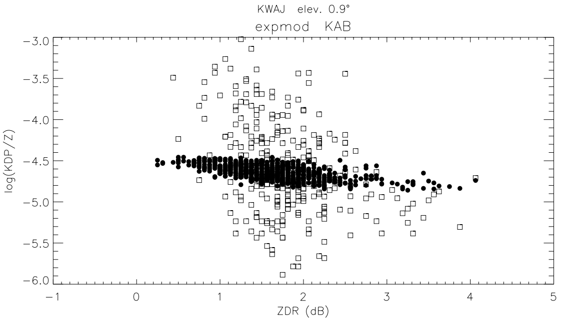

Figure 2: Scatter diagram of $\log_{10}[K_{DP}/Z]$ vs. Z_{DR} (K_{DP} is in deg. km^{-1}, Z is in mm^6 m^{-3} and Z_{DR} is in dB). (●) symbol is related to K_{DP} retrieved by ZPHI, and (□) symbol corresponds to K_{DP} obtained by regression approach.

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