P5R.4 SIMULATION OF THE BRIGHTNESS TEMPERATURE OF SPACEBORNE MICROWAVE RADIOMETER BY USING COBRA DATA

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1. INTRODUCTION

One of the important issues for the rain retrievals with a spaceborne microwave radiometer is the drop size distribution (DSD) model, because retrieval algorithms use the relationship between the brightness temperature (TB) and the rain rate is generally calculated from the prefixed rain structure model with a fixed DSD parameters (typically Marshall-Palmer DSD is used). For this reason, a rain model with the information of DSD, phase, density, fall velocity and so on is required to evaluate the retrieval error. Multi-parameter radar is suitable to establish such kind of rain model. In this study, brightness temperatures of low frequency channels of a spaceborne microwave radiometer are simulated by using a ground based multi-parameter radar data in order to construct the basis of the rain model and the simulated TB field is compared with the simultaneous observation by TRMM/TMI. The simulation is also done by using the rain profile of the TRMM/PR to evaluate the DSD model used in the PR's algorithm. The DSD model is evaluated by the DSD data obtained from a ground based multiparameter radar.

2. DATA

Data used in this study was obtained in June 2004 at Okinawa Island, Japan (sub-tropical region in Japan) during Baiu (rainy) season. Two cases data when the TRMM satellite flew over Okinawa (June 1 and 2) are used in this study. The case on June 1 is relatively wide spread convective system with stratiform rainfall and the case on June 2 is more scattered convective system. On June 1 case, only TMI data is available within the ground based radar range, while both TMI and PR data are available on June 2. The details of the data are explained in the following subsections.

2.1 *COBRA*

The CRL Okinawa bistatic multiparameter radar (COBRA) is C-band radar developed in 2001 (Nakagawa et al., 2003). Table 1 shows the major specification of COBRA. It has capability to transmit horizontal (H) and vertical (V) polarization channel simultaneously by two transmitters (two Klystrons or two TWTAs) and simultaneous reception of H and V channels (see Fig. 1). This radar has advantage that any polarization status can be realized with this system. The polarization used in this observation was +45º linear polarization transmission and 14 elevation angles of PPI and 3 RHI scans were operated 10 minutes intervals. The parameter of Z_{HH}, Z_{DR}, $\rho_{HV}(0)$, and $\Phi_{DP}(K_{DP})$ are used for the retrievals and the analysis.

Table 1. Major specification of COBRA

Peak power	> 250 kW (Dual Klystron)
	> 10 kW (Dual TWTA)
Pulse width	0.5, 1.0, 2.0 μs (Klystron)
	0.5 – 100 μs (TWTA)
PRF	250 - 3000 Hz, 1 Hz step
	(staggered PRF)
Antenna size	4.5m ϕ parabolic
Beam width	< 1.1 deg
Radome size	8m ϕ
Antenna gain	> 36 dB
	(Integrated value in a beam)
Cross pol. ratio	> 42 dBi (including radome)
Sidelobe	< -25 dB (one way)
Ant. scan speed	0.5-10 rpm (PPI)
	0.1-3.6 rpm (RHI)
Polarization	H, V, +45, -45, LC, RC
	(available to switch pulse by pulse)

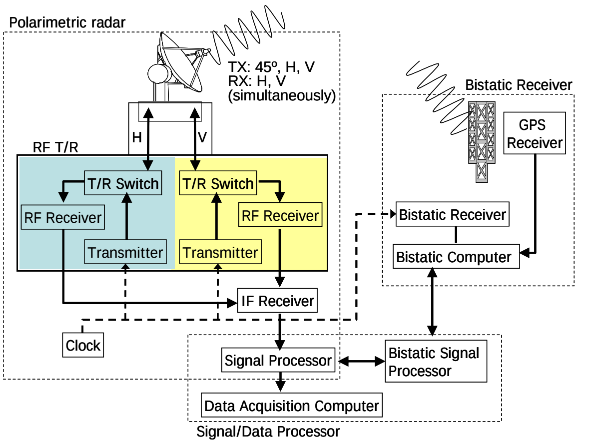

Fig.1. Schematic illustration of COBRA system

2.2 *TRMM/PR*

A Ku-band (13.8 GHz) spaceborne radar, TRMM/PR is the world first spaceborne precipitation radar. The standard algorithm of TRMM/PR (2A25, Iguchi et al., 2000) provides the attenuation corrected reflectivity factor (*Z*) profiles by Hitschheld-Bordan (1954) or the surface reference technique (SRT, Meneghini et al., 2000) as well as rain rate (*R*) profiles.

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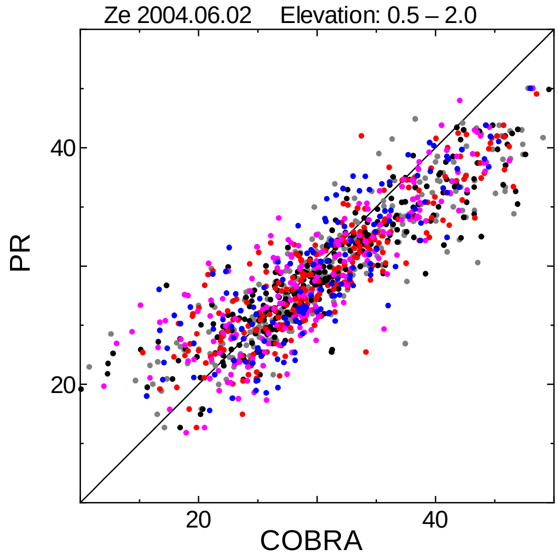

Fig.2. Scatter diagram of Z_e between PR and COBRA for elevation angles from 0.5 to 2.0º.

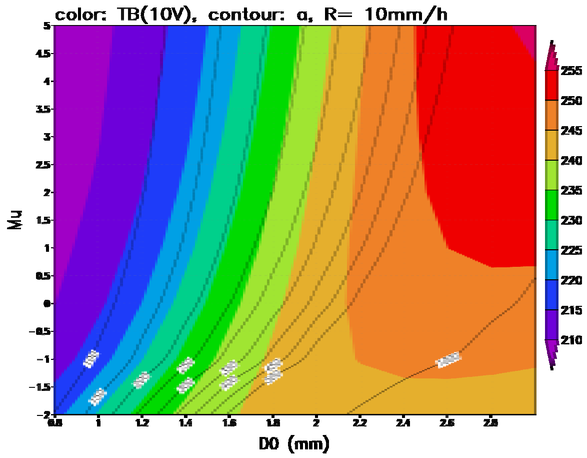

Fig.4. Brightness temperature for variable DSD parameter μ and D0 with fixed rain rate. Solid lines show the isopleths of Z-R relationship.

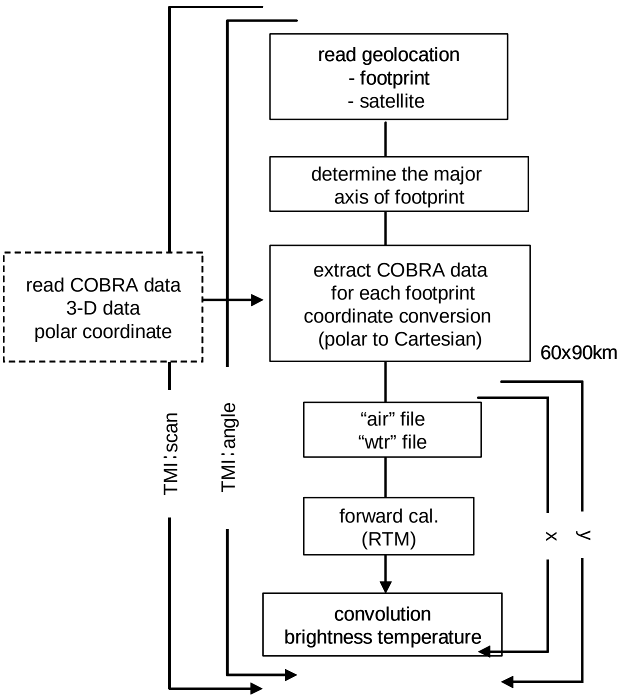

Fig.3. Schematic illustration of the retrieval procedure of brightness temperature from the COBRA data.

When the SRT is used DSD parameter (Z-R relationship) is adjusted to satisfy the path integrated attenuation. The adjustment parameter (ε) and the resultant Z-R parameters are also included the product.

The effective radar reflectivity factor (Z_e) from PR and COBRA are compared in order to check the calibration of COBRA and location matching. Figure 2 shows the scatter plot of Z_e between PR and COBRA. Since the both radar are calibrated by active radar calibrators independently, the scatter plot shows good agreement each other, especially for the weaker Z_e. The Z_e from COBRA becomes larger than that from PR as the Z_e goes higher, it is probably because the Mie scattering effect in the *Ze* of PR.

3. ANALYSIS METHOD

Figure 3 shows the flow chart for the brightness temperature from COBRA data. Three dimensional data set of Z_e (or R or DSD) is prepared for each TMI pixel because the TMI foot print is 36 x 60 km oval shape (10 GHz) and the beam direction (direction of the major axis of the oval) changes with the scan angle. In this paper, 60 x 90 km area along the beam direction is prepared for each footprint to cover about 1.5 times of the foot print area with 1 km horizontal resolution and 0.5 km vertical resolution. For each grid point, radiative transfer calculation is implemented by using a plane parallel model developed by Liu (1998). The brightness temperature calculated in each grid point is averaged over the area weighted by the antenna pattern of TMI. This is compared with the observation. Note that the ocean area data is compared because the contribution of rain to the TB is small over land.

The calculation of the brightness temperature from the TRMM/PR is basically the same manner as the calculation with COBRA data except for the horizontal resolution is 5 km and vertical resolution is 0.25 km. The standard product 2A25 contains not only the R profile but also "a" and "b" parameter in Z-R ($Z=aR^b$) relationship which is calculated from the attenuation

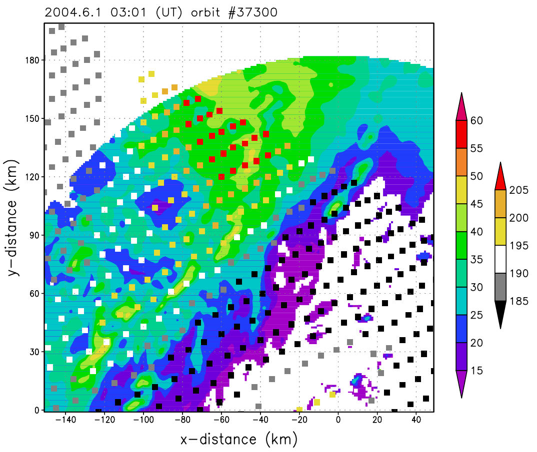

Fig. 5. The CAPPI image of COBRA at as altitude of 2 km during TRMM over flight at 03:01 UT on June 1, 2004 (orbit number is 37300). TMI 10GHz vertical polarization brightness temperature is also plotted by squares.

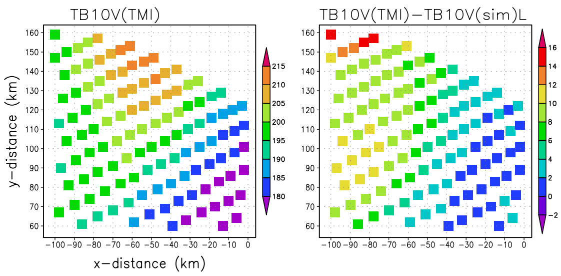

Fig. 6. The brightness temperature field of 10 GHz vertical polarization from TRMM/TMI (left) and the difference between the observation and the calculation from COBRA data (right). Typical Z-R relationship *Z=200R*$^{1.6}$ is used for the calculation of the brightness temperature.

adjustment parameter ε which control the attenuation *(k)* and *Z* relationship ($k{=}\varepsilon\alpha Z^{\beta}$). Therefore, ε is a kind of DSD parameter and it is outputted in 2A25. If we assume the relationship between *k* and *R* is independent from ε (e.g. $k{=}cR^{d}$, where *c* and *d* are constant), the "a" parameter in Z-R relationship will be expressed as $a = \left(c/\varepsilon\alpha\right)^{1/\beta}$. In this sense, the Z-R relationship is suitable for the comparison of the DSD model of PR with COBRA.

The Z-R relationship ($Z{=}aR^{b}$) is used for the retrieval of the brightness temperature by the COBRA data. The parameter "a" is adjusted to satisfy the observed brightness temperature. The optimum Z-R relationship from the observation Ze and the R are compared with the Z-R relationship from the

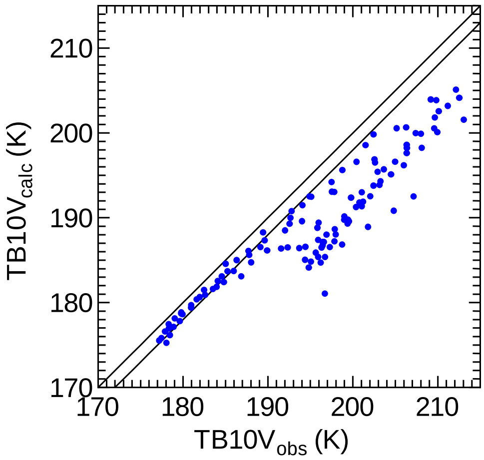

Fig. 7. Scatter plot of 10 GHz vertical polarization brightness temperature between the observation and the calculation from COBRA on the case shown in Fig. 5.

multiparameter data and DSD parameter from TRMM/PR. Two algorithms are applied to estimate the rain rate from multiparameter radar data: one is R(K_{DP}) algorithm and the other is R(Z_e,Z_{DR}) algorithm (Bringi and Chandrasekar, 2001). Please note that the melting layer model is not introduced in this calculation though the melting layer causes larger TB. The simple DSD model is desired for the practical application to the radiometer algorithm. The model calculation (Fig. 4) shows that DSD model of fixed Z-R relationship leads good coincides with the brightness temperature for 10 GHz.

The "a" parameter is also estimated from rain rate and Z value from COBRA data. The rain rate is estimated from K_{DP} and from the combination of Ze and Z_{DR}.

4. RESULT

Figure 5 shows CAPPI image of Z from COBRA at an altitude of 2 km together with TB from TMI (10 GHz vertical polarization) on June 1. High reflectivity region coincides well with the high TB region. Since the footprint size of the TMI 10GHz channel is very large, TB field is more blurred pattern. Figure 6 shows the TB field from the observation and the difference in TB between observation and calculation from COBRA data with fixed Z-R parameter (Z=200R$^{1.6}$) and Fig. 7 shows the scatter plot between the TBs. At the lower TB region both estimations coincided well each together with about 2 K offset (It may be cause by the difference in the surface condition between the actual and model. Under estimation up to 10 K is seen above 190K. One possible reason of the difference is the DSD model and the effect of melting layer. Several Z-R models are used to calculate the

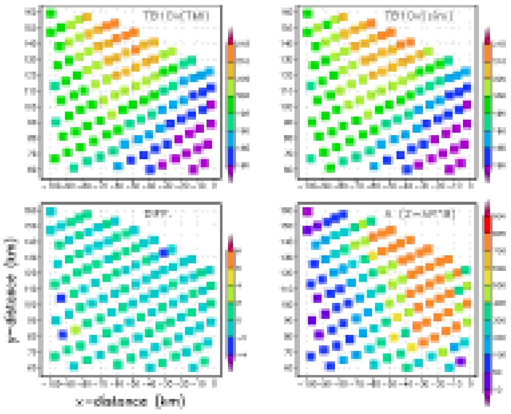

Fig. 8. Horizontal pattern of 10 GHz vertical polarization brightness temperature of TMI observation (left top), the best fit calculation from COBRA data (right top), the difference between two brightness temperature field (left bottom) and the optimum Z-R parameter "a" (right bottom) .

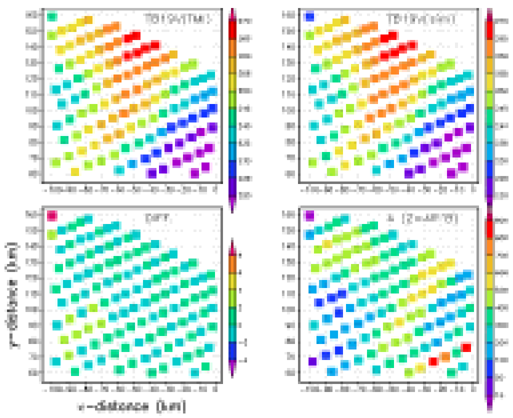

Fig. 9. Same as Fig. 8 except for 19 GHz.

TB field to find the optimum Z-R parameter. The optimum Z-R parameter (the "a" parameter in the Z-R relationship) is shown in Fig. 8. The value "a" ranges from 100 to 800 except for weak echo region. The "a" field from 19 GHz channel (Fig. 9) shows similar pattern to the 10 GHz case except for the high "a" region and "a" ranges from 100 to 500. The difference in "a" value between 10 GHz and 19 GHz is partly caused by the sampling area of COBRA. The retrieved "a" field from COBRA data by using the rain rate estimated by two methods $R(K_{DP})$ and $R(Z_{DR},Z)$ (Bringi and Chandrasekar, 2001) are shown in Fig. 10 and similar tendency with 19 GHz channel result appears: high reflectivity region corresponds to smaller "a" value and surrounded by relatively high "a" region.

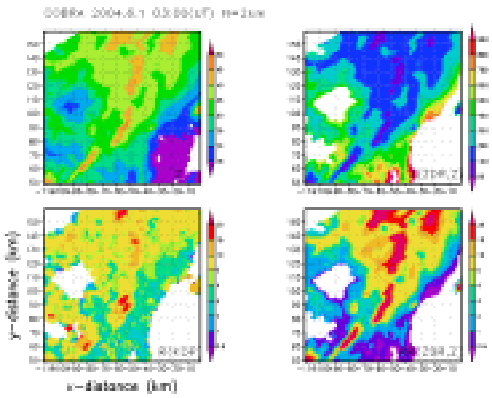

Fig. 10. *R* from K_{DP} (left bottom), *R* from Z_{DR} and *Z* (right bottom), *Z* (left top), and estimated "a" in Z-R relationship ($Z=aR^b$) by using $R(Z_{DR}, Z)$ and *Z* (right top) from COBRA data of 2km in height.

The comparison of three measurements of TRMM/TMI, TRMM/PR and COBRA is available for the case on June 2, 2004 (not shown). This is the case of scattered convective system. Retrieved TB field from PR data shows similar pattern with the observation and the ε shows small variation, because the 2A25 gives $\varepsilon=1$ for weak rain fall where the attenuation is not significant and the data is averaged over large TMI footprint size. The optimum "a" field from COBRA shows similar tendency with ε, but the value is quite different.

5. DISCUSSION AND SUMMARY

In this study, TB field is retrieved by COBRA data in order to estimate the effect of DSD. The Z-R relationship is suitable to express the DSD model in the retrieval for the microwave radiometers based on the radiative transfer calculation with simple rain model.

The method to find the optimum "a" parameter in the Z-R relationship implicitly assumes the single DSD model with in a TMI footprint. In this point, the results from Z-R model by COBRA, PR data, and the Z-R estimation of multiparameter radar data are not always agree each other. However the result seems similar in quality. There are inconsistency in the simulated "a" field between 10 GHz and 19 GHz. The effect of melting layer and surface condition should be considered to explain the difference.

Only rain layer is focused in this study because the low frequency channels are insensitive to the solid precipitation (precipitation above freezing level). Since the goal of this study is establish the rain structure model based on COBRA data that satisfies the TMI observation, the retrieval experiment for higher frequency channels should be conducted. For this purpose, multiparameter radar observation is important because solid precipitation is hard to model in terms of particle density, fall velocity and shape.

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