P3.26 **VALIDATION OF GMS BRIGHTNESS TEMPERATURE DIFFERENCE TECHNIQUE FOR ESTIMATE OF CUMULONIBUS IN TYPHOON BY TRMM PR DATA**

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1. INTRODUCTION

TRMM is considered as a powerful tool for watching tropical cyclones such as a typhoon. From a image of TRMM PR, 3-D structure of precipitational area of typhoon is easily understood. The distribution of rain area and wind field are also found widely by TRMM TMI. But TRMM is one of LEO satellites and it can observe the typhoon only two or three times a day. Because of this reason, it is needed to use both Geostationary Meteorological Satellite (GMS) and TRMM for analysis of typhoons still now.

For the analysis of typhoon using GMS images, it is important to understand typhoon intensity which has strong connection to cumulonimbus (Cb) in typhoon. For the estimate of typhoon intensity, infrared image of GMS are used as Dvorak technique (Dvorak, 1984). Because there is a possibility that low brightness temperature area consists of cirrus from Cb in typhoon, the typhoon intensity can be estimated from the condition or shape of low brightness temperature area. This technique is depend on the cirrus, which has indirect connection to typhoon intensity. If Cb in typhoon connected directly to its intensity can be detected from GMS image, the accuracy of the technique will be improved.

Using TRMM PR image, Cb in typhoon can be found easily. But because of its low observational frequency and narrow observational area, TRMM cannot estimate typhoon intensity continuously.

Recently new algorithm to identify Cb has been developed using Brightness Temperature Difference (BTD) between brightness temperature of infrared channel (BTir) and that of water vapour channel (BTwv) (Ackerman,1996; Kurino,1997; Schmetz *et al.*,1997). Velden and Olander (1998) showed the possibility of this method to estimate tropical cyclone intensity more precisely.

This paper presents a result of validation of this new technique using TRMM PR data. Firstly, images of GMS BTD are compared with that of TRMM PR. Secondly, superiority of BTD to BTir is shown about the sensitivity to rain intensity. Lastly, BTD is classified into every 1 K. Then the grid points number, which include Cb in TRMM PR data, is accounted in each classified BTD, and some statistical elements are calculated. Using these elements, the range of BTD, in which Cb can be detected efficiently, is confirmed.

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2. DATA

GMS data were collected in CD-ROM of ‘Monthly Report of Meteorological Satellite Center’ made by Japan Meteorological Agency (JMA). The GMS data are limited to the domain from 20ºN to 50ºN latitude and from 120ºE to 150ºE longitude. Spatial resolution of GMS data is 0.06º and time resolution is one hour. TRMM PR data were obtained from NASA and rain rate in 2A25 data set was used. The best track data of typhoon were derived from Regional Specialized Meteorological Centre Tokyo analysis. This comparison were done using the data in 1998 and 1999.

There were 83 cases in which TRMM observed typhoons in this period over this domain. Among them, 19 cases were chosen when typhoon centers were included in GMS data domain, and TRMM passed the centers within 10 minutes of GMS observation.

3. TECHNIQUE FOR ESTIMATING Cb USING BTD

BTD between BTir and BTwv of GMS are defined as below,

$$BTD = BTir - BTwv.$$

According to Schmetz *et al.*(1997), BTir over Cb or dense cirrus which reached to stratosphere shows only the cloud top temperature. On the other hand BTwv includes both cloud top temperature and the radiation from the water vapour in the stratosphere. So BTwv is usually higher than BTir over the Cb or dense cirrus overshooting the stratosphere. If BTD is negative, it can be guessed that there are Cb or dense cirrus at that negative BTD area.

4. COMPARISON OF GMS IMAGES IN TYPHOON REX AND TYPHOON VIRGIL

Fig. 1(a) shows image of BTir and BTD in Typhoon Rex observed by GMS at 22:31(UTC) 30 Aug. 1998. The area, in which BTD is below 0 K (BTD<0), is found near the surroundings of typhoon’s eye located at 31ºN and 143ºE. There is another BTD<0 area concentrated in the east side of the eye. And in the south eastern part of typhoon, line shaped BTD<0 area are scattered. BTD<0 area surrounding the eye corresponds to eyewall of typhoon. BTD<0 areas in the east to south eastern part of typhoon also corresponds to rain bands which are surrounding the outer side of the typhoon. Fig. 1(b) shows the image of rain intensity at the altitude of 4.0 km observed by TRMM PR at 22:22(UTC) 30 Aug. 1998.

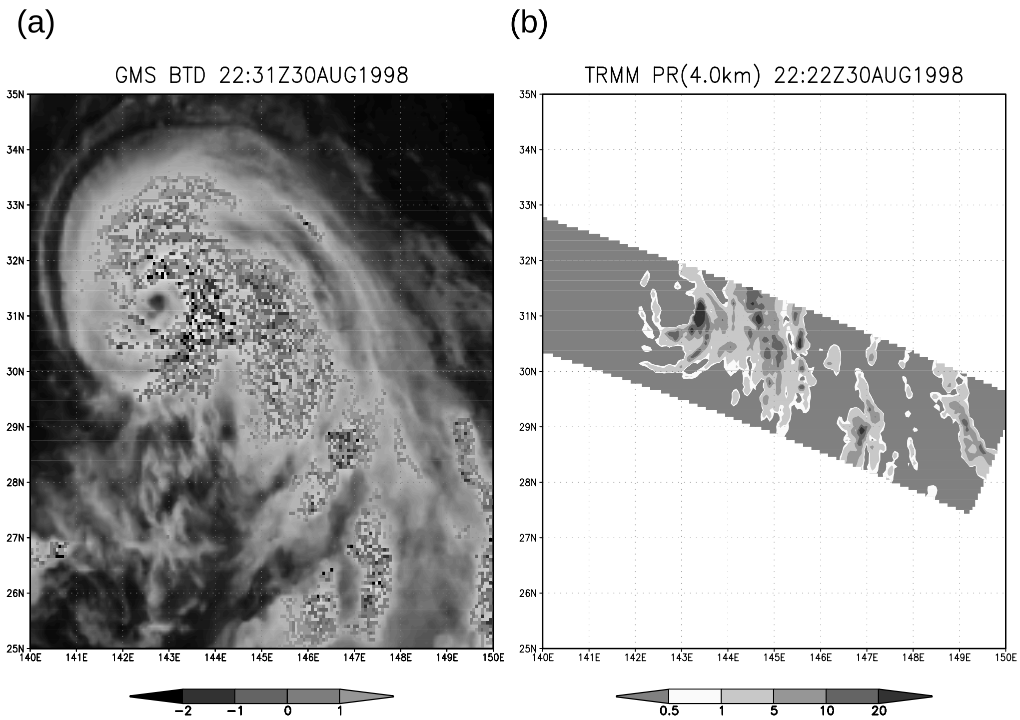

Fig. 1 (a) Image of BTD (K) in Typhoon Rex observed by GMS at 22:31(UTC) 30 Aug. 1998.
(b) Image of rain intensity (mm/hr) in same typhoon at the altitude of 4.0 km observed by TRMM PR at 22:22(UTC) 30 Aug. 1998.

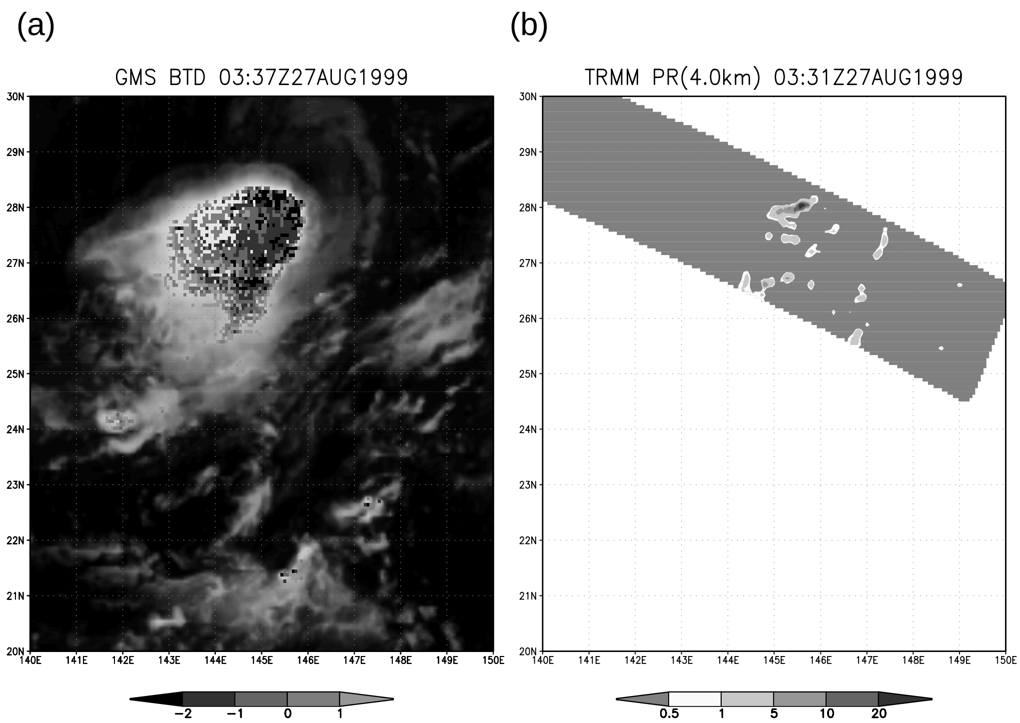

Fig. 2 (a) Image of BTD (K) in Typhoon Virgil observed by GMS at 03:27(UTC) 27 Aug. 1999.
(b) Image of rain intensity (mm/hr) in same typhoon at the altitude of 4.0 km observed by TRMM PR at 03:31(UTC) 27 Aug. 1999.

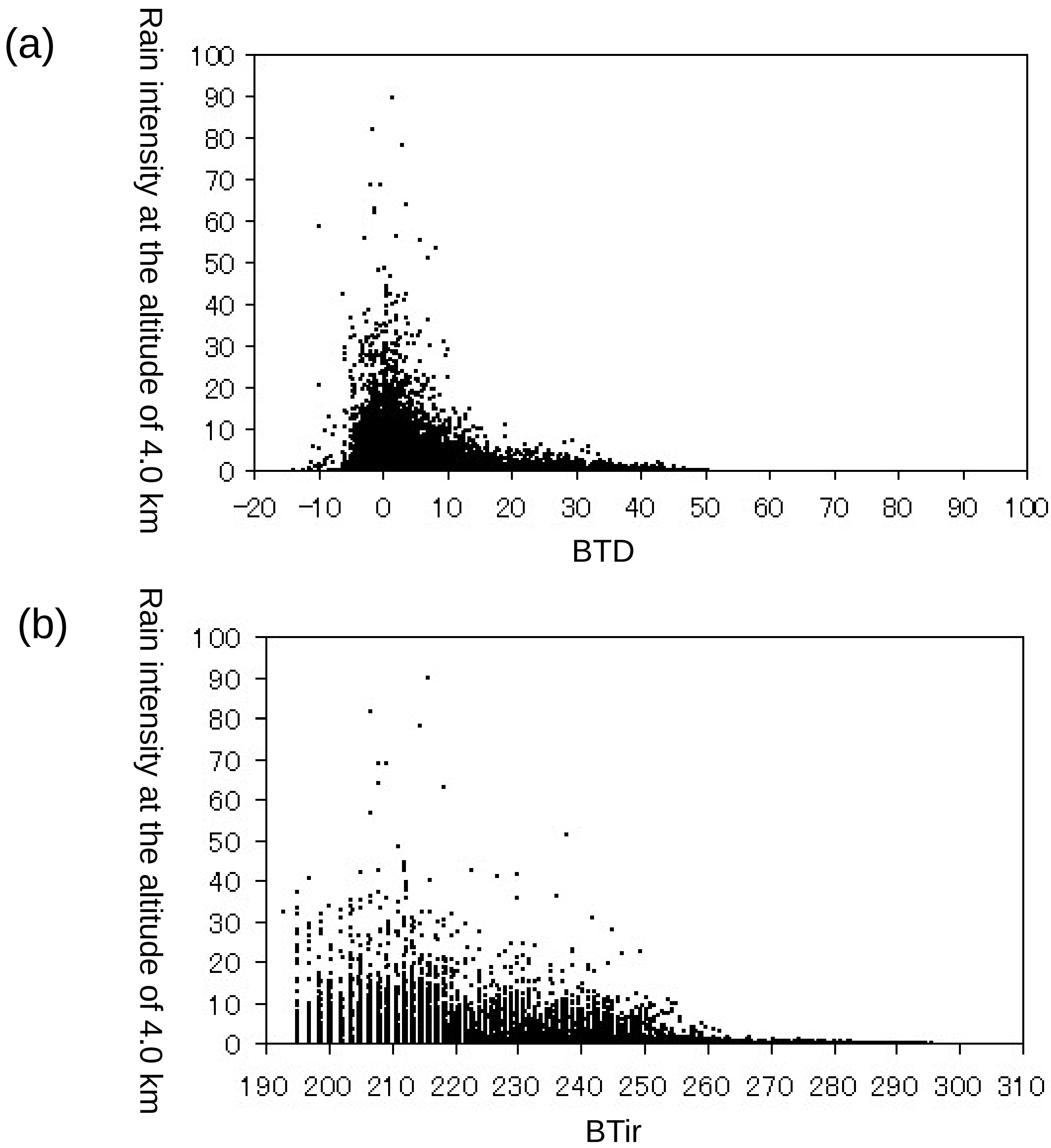

Fig. 3 (a) Scatter diagram BTD (K) and rain intensity (mm/hr) at the altitude of 4.0 km.

(b) Scatter diagram BTir (K) and rain intensity (mm/hr) at the altitude of 4.0 km.

BTD (K)	−5〜−4	−4〜 -3	-3〜 -2	-2〜 -1	-1〜 0	0 〜 1	1〜 2	2 〜 3	3 〜 4	4 〜 5	5 〜 6	6 〜 7	7 〜 8	8 〜 9	9 〜 10
Grid num. of Rain points	95	234	483	766	1460	2320	2450	2446	1594	1183	919	754	683	553	424
Grid num. of Cb points	36	64	96	205	331	554	410	379	196	144	93	56	73	57	37
Cb POD (%)	1.3	2.2	3.4	7.2	11.6	19.4	14.3	13.3	6.9	5.0	3.3	2.0	2.6	2.0	1.3
Cb hit rates (%)	37.9	27.4	19.9	26.8	22.7	23.9	16.7	15.5	12.3	12.2	10.1	7.4	10.7	10.3	8.7

Table. 1 Classified BTD, grid number of rain points, Cb points, Cb POD and Cb hit rates

Strong rain intensity areas are found at the surrounding of the eye and the east to south eastern part of typhoon. These areas show Cb clusters. Comparing Fig. 1(a) with 1(b), it is easy understood that BTD<0 areas corresponds to Cb qualitatively.

Fig. 2(a) shows image of BTir and BTD in Typhoon Virgil observed by GMS at 03:37(UTC) 27 Aug. 1999. The typhoon's eye is located at 28.5ºN and 146ºE. The cloud cluster is found only the south western part of the eye. Most part of the cluster is covered by the area of BTD below -1 K. Fig. 2(b) shows the image of rain intensity at the altitude of 4.0 km observed by TRMM PR at 03:31(UTC) 27 Aug. 1999. There are few rain falling areas in the PR image. BTD<0 area (including BTD<-1) does not corresponds to strong rain intensity area. From the judgment of the life cycle of this typhoon, BTD<-1 area shows dense cirrus cloud. This Virgil case is different from Rex case in Fig.1, and BTD<0 area does not means Cb in this case.

5. COMPARISON OF BTD AND RAIN INTENSITY GRID BY GRID

In previously mentioned 19 cases, BTD of GMS images and rain intensity of TRMM PR are compared grid by grid. Grids of PR data were interpolated to match with grids of GMS data. In each cases the domain of comparison is a rectangle (6º lat.×6º lon.) in which each typhoon's eye is centered.

Fig. 3(a) shows comparisons between BTD and rain intensity at the altitude of 4.0 km at all 73,506 grids in all cases. All grid points are found from -10 K to 50 K in BTD. Especially from -5 K to 10 K in BTD there are grid points which have strong rain intensity above 10 mm/hr. According to referenced papers, grid points of BTD<0 mean Cb. But from this figure, it is supposed that grid points include Cb in the case of not only negative BTD but also positive BTD.

Fig. 3(b) shows comparison between BTir of GMS and rain intensity. All grid points are found widely from 195 K to 295 K in BTir. Grid points which have strong rain intensity above 10 mm/hr are distributed from 195 K to 260 K in BTir. The range of the BTir is wider than that of BTD. From the comparison between the range of BTD in Fig. 3(a) and BTir in (b), it is found that BTD coincide to strong rain intensity grid points at narrower temperature range than BTir.

6. CLASSIFIED BTD AND Cb

Table1 shows classified BTD and grid number of rain points, Cb points, Cb POD (Probability Of Detection) and Cb hit rates.

Rain points mean the cases in which the points have rain intensity above 0.5 mm/hr at the altitude of 4.0 km. Cb points mean the cases in which the points have rain intensity above 5.0 mm/hr from the altitude of 3.0 km to 5.0 km continuously. Cb POD means the percentage of grid number of Cb points in the classified BTD to all grid numbers of Cb points in the whole domain. Cb hit rates means the percentage of grid number of Cb points to grid number of rain points in the classified BTD.

In this table, Cb POD above 10 % is found in classified BTD from -1 K to +3 K. Cb hit rates above 20 % is also found in classified BTD below +1 K. So BTD below -1 K show high percentage of including Cbs in that classified BTD (Cb hit rates), but catch few Cbs in whole domain (Cb POD). In the meanwhile, BTD above +1 K has many Cbs in the domain (Cb POD), but the percentage of including Cbs in the classified BTD is low (Cb hit rates). In conclusion, when BTD from -1 K to +1 K is used, it can detect Cb efficiently.

From this table and Fig. 1, it is validated that BTD from -1 K to +1 K can identify Cb in typhoon at high percentage. And from this table and Fig.2, it is supposed that BTD below -1 K does not show Cb, it identify dense cirrus. But this guess is not confirmed yet.

7. SUMMARY

Cb has a direct relation to typhoon intensity. This study showed that BTD from -1 K to +1 K can identify Cb in typhoon efficiently. And BTD is also more sensitive to strong rain intensity in typhoon than BTir which is now used to estimate the typhoon's intensity. BTD has a potential to become a very useful tool for objective estimation of typhoon intensity

In future, the reliability of this BTD technique will be improved using new data in wider domain for validation. And this technique will be applied to objective estimation of typhoon intensity.

8. REFERENCES

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