Article ID: 1006-8775(2001) 02-0218-07

OBSERVATION RESEARCH FOR THE MEASURING RAINFALL CAPACITY OF TRMM/TMI-85.5G BASED ON PRECIPITATION DATA DURING THE HEAVY RAIN EXPERIMENT IN SOUTHERN CHINA

LU Yan-bin (吕艳彬), GU Lei (顾　雷), LI Ya-ping (李亚萍), GAO Hui-lin (高慧林), SHAO Ming-xuan (邵明轩), TAO Zu-yu (陶祖钰)

(*State Key Laboratory for Severe Storm Research*, *Peking University, Beijing*, 100871 *China*)

ABSTRACT: The capacity of Tropical Rainfall Measuring Mission (TRMM) Satellite for measuring rainfall was examined by using TMI-85.5 GHz microwave image data and precipitation data during a heavy rainfall experiment in southern China. From comparisons with the distribution of rain amount in an hour with T_{BB} of 85.5 GHz microwave, it is clear that the center of heavy rain corresponds with an area of low T_{BB} value. The location and shape of T_{BB} distribution is similar to that of precipitation, and the larger the rainfall rates, the lower the T_{BB}. A statistic analysis shows that the correlation coefficients between T_{BB} and rain rates is negative and significant. Especially, when the rain rate is over 7 mm/h, the correlation degree between T_{BB} and rain rates is more significant. The results shows that TRMM/TMI-85.5 G has great ability to measure convective heavy rain.

Key words: microwave remote sensing; precipitation; statistics

CLC number: P414.1 **Document code:** A

1 INTRODUCTION

The Tropical Rainfall Measuring Mission (TRMM) satellite was jointly launched by the United States and Japan in November 1997. Aiming at acquiring more understanding of the effect of tropical precipitation on global climate systems, it was a mission in space aircraft for initial qualification of tropical rainfall measurements[1]. Detectors onboard the satellite included a microwave imager, precipitation radar, visible and infrared radiometer, lightening detector and earth radiation detector. With a swath of 760 km, the microwave imager with 5 frequencies was to measure the intensity of precipitation over the ocean over 5 frequencies. The frequency of 85.5 GHz with horizontal resolution of 4.4 km, was specially designed for detecting convective precipitation on the mesoscale and fine scale.

The physical mechanism[2] with which convective precipitation is sensed with microwave at 85.5 GHz is based on the fact that ice crystals in the upper portions of convective systems scatter the 85.5-GHz-microwave intensely, which leads to considerable reduction of the upward radiation

Received date: 2001-03-28; **revised date:** 2001-08-15

Foundation item: Scaling Project 95-special project-03; G1998040907; Natural Science Foundation of China (49735180); Foundation for Visiting Scholars for Higher Education Colleges

Biography: LU Yan-bin (1969 –), female, native from Shanxi Province, engineer, Master degree holder, mainly involving in the study of mesoscale meteorology and working at the weather station of CAAC Tianjin airport.

emitting from lower levels. In the meantime, crystals in the upper portion of the rain area are cold and have small contribution to the upward radiation. Therefore, the thicker the crystal layer, the weaker the outgoing microwave radiation will be at 85.5 GHz. As indicated in the theory of cloud physics, updrafts in severe meso-and fine-scale convective systems are stronger, the crystal layer is thicker and the rain rate is larger. It is then seen that the most advantageous point about the 85.5 GHz sensing is that it enables the measurement of severe precipitation produced by convective clouds but remains insensitive to continuous precipitation in which there are not any crystal layers at higher levels. It is necessary to exploit the observed rainfall measurements to confirm the capacity of the imager in detecting severe convective precipitation. In the current work, hourly rainfall data in 3 of the intensive observation periods in June (IOP5, 6, 7), which are selected from a scientific experiment of heavy rain across the Taiwan Straight performed in Guangdong and Fujian provinces in the early summer of 1998, are used to investigate into the rain-measuring capacity by TRMM/TMI-85.5 GHz.

2 DATA AND METHODS

The TRMM satellite is near-equatorial and non-solar-synchronous-orbiting, with the orbital height about 350 km, inclination of 35°, 15.77 orbits per day and a life cycle of 3 years. It covers low latitudes between 40° in the south and north latitudes. The TRMM satellite irregularly passes over the south of China. By studying all microwave images taken by TRMM/TMI in June 1998, we find that only 9 time levels in 3 IOP (5, 6, 7) of the month (Tab.1) have good coverage of the Guangdong and Fujian provinces. Fig.1 gives one of the microwave images by TRMM/TMI-85.5 GHz at 14:09 Z (GMT, same below), June 8. T_{BB} data for the 9 time levels and hourly rainfall at 128 stations during the intensive observation periods in the provinces in June are used in the study.

Tab. 1 Coefficients of correlation between T_{BB} and rain rates at different time levels

Observation time by TMI-85.5 GHz (Z)	Duration of 1-h rainfall (Z)	Number of stations covered	Critical values of correlation coefficient (confidence degree 1 %)	Correlation coefficients
16:32, 2 Aug.	16:01～17:00	107	0.254	-0.641
16:56 3 Aug.	16:01～17:00	84	0.283	-0.589
	17:01～18:00			-0.669
23:24 3 Aug.	23:01 3 Aug. ~ 00:00 4 Aug.	71	0.302	-0.499
15:43 4 Aug.	15:01～16:00	111	0.254	-0.333
14:07 8 Aug.	13:01～14:00	127	0.228	-0.611
	14:01～15:00	126		-0.614
20:35 8 Aug.	20:01～21:00	96	0.267	-0.570
12:54 9 Aug.	12:01～13:00	104	0.254	-0.599
19:46 10 Aug.	19:01～20:00	76	0.302	-0.768
	20:01～21:00			-0.653
08:27 18 Aug.	08:01～09:00	109	0.254	-0.367

As the first step in the study, contours of T_{BB} and distribution of 1-h rainfall are plotted in association with the TMI-85.5 GHz microwave images and comparison is made between the distribution of T_{BB} and rain rates. Then, coefficients of correlation between them for each of the

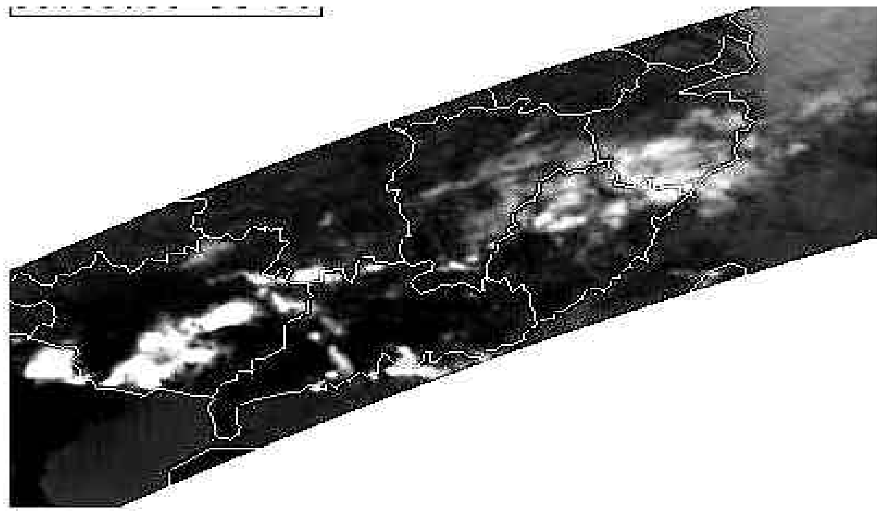

Fig.1 TRMM/TMI-85.5 GHz microwave image (14:09 Z, June 8, 1998)

time levels are computed[4]. In the computation, the T_{BB} values are the minimums within two 0.3-lat.×long. domains centered at rain-recording stations (As such data are in regular 0.2×0.2 grid-points while the stations are discrete points spreading irregularly, and gridpoints with minimum T_{BB} usually do not coincide with that of stations. The minimum values are taken to highlight the relationship to rain rates). For a T_{BB} map that covers the region of southern China (Fig.1), the TRMM satellite takes a duration about 5 min. in measurement and travels over it with varying daily time and frequency. In contrast, rain rates are data cumulated over the past hour and recorded at every hour regularly. They are therefore taken as the 1-h value at the very time level at which or 2 time levels around which the TRMM satellite makes the measurement (12 time levels fall into the provision, which are presented in Tab.1). Lastly, all data of rain rates are classified according intensity to determine the coefficient of correlation with T_{BB}. The classification is done in two ways. One is a stepwise increase by the unit of 1 mm/h starting from the grade of rain presence (with a rain rate $\geq$ 0.1 mm/h) and the other is a division of 4 grades of rain rates ranging from a to d (See Tab.2).

3 COMPARISON OF DISTRIBUTION OF T_{BB} AND 1-h RAINFALL

Fig.2 gives the contours of T_{BB} at 12:54 Z, June 9 by TMI-85.5 GHz and the 1-h rainfall spread between 12:01 Z and 13:00 on the day. It shows that there are two centers of rainfall in central-to- eastern Guangdong and eastern Fujian, with two cores of high rain rate, 14.6 mm and 12.2 mm respectively, corresponding to low T_{BB} areas, which is lower in the former than in the latter. The figure also presents a rain center more than 3 mm at the southeast border of Guangdong in association with a relatively high low-T_{BB} area. As indicated in the rainfall contours relevant to the T_{BB} values in Fig.3, the two rainfall centers in Guangdong and Fujian are similar to the two low-T_{BB} areas in both location and shape. The comparison and analysis above show that a strong rainfall center is generally associated with low T_{BB} areas. The higher the rain rate, the lower the

T_{BB} will be. It is an indication that the intensity of rain rates is closely related with the T_{BB}.

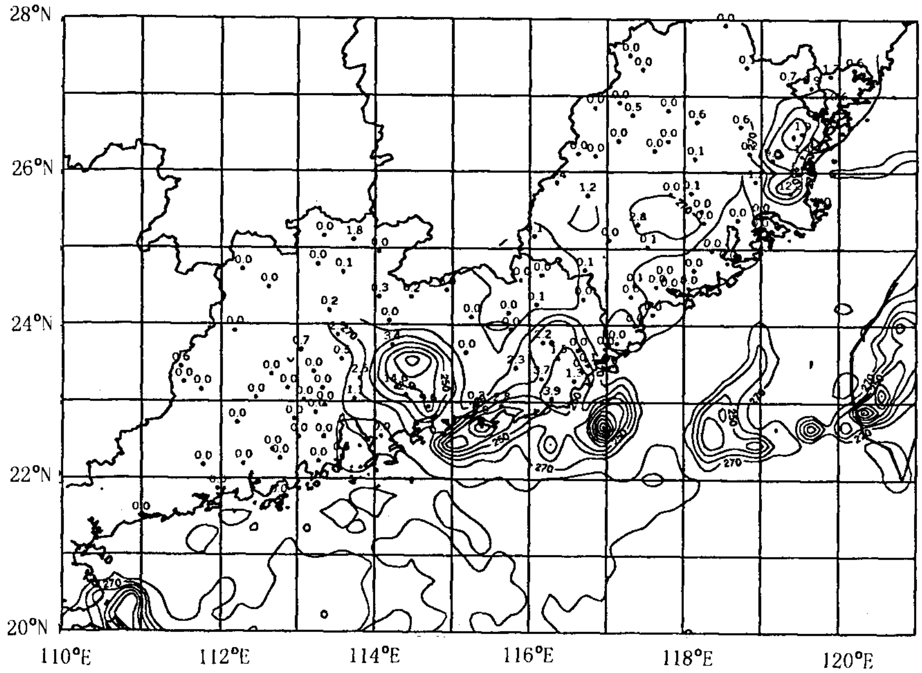

Fig.2 The isotherm of T_{BB} at 12:54 June 9, 1998 (starting form 270 K at intervals of 10 K) and the scatter of the 1-h precipitation records of 12:01 ~ 13:00 on the day (unit : mm).

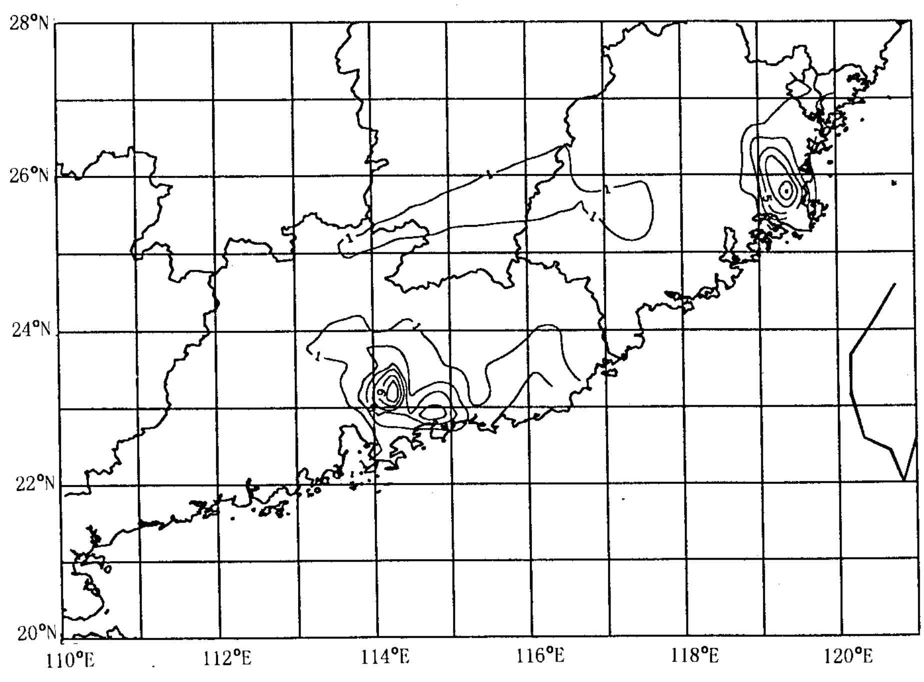

Fig.3 The distribution of 1-h precipitation (at the same as in Fig.2) (starting from 1 mm at intervals of 2 mm).

Tab.2 The grades and range of rain rate and the number of available records

Grade of rain rate	a	b	c	D
Range of rain rate (mm/h)	0.1～0.4	0.5～2.9	3.0～6.9	≥7.0
Number of available records	138	150	64	43

4 STATISTICAL RELATION BETWEEN T_{BB} AND RAINFALL

4.1 *Overall correlation of distribution between* T_{BB} *and rain rate*

Tab.1 gives the coefficient of correlation between T_{BB} and rain rate at individual time levels and its critical values with 1% confidence degree. It is shown in the table that the correlation of T_{BB} with rain rates is significantly negative and the confidence is at the level of 1% for all the time levels with confidence level at 99%. The correlation coefficients listed therein are a quantitative display that the overall distribution of T_{BB} is well correlated with the rain rate at all time levels such that the larger (smaller) the rain rate, the lower (higher) the value of T_{BB}. It illustrates that the TMI-85.5 GHz is a stronger measuring tool of precipitation.

4.2 *Correlation between rain rates of varying degrees and* T_{BB}

To have deeper understanding of the relationship between the intensity of the rain rate and the T_{BB}, Fig.4 gives the distribution of coefficients of correlation between rain rates of varying degrees and T_{BB} and the corresponding critical values of a 5% confidence degree. The number of available rainfall records covered by corresponding T_{BB} is also included in the figure. As is shown, the correlation coefficient is the highest when the rain rate > 0 mm/h and the number of rainfall records is the largest and confidence level (far greater than 95%) is the highest. Again it shows how well the TMI-85.5 GHz microwave could do in monitoring precipitation. When the rain rate gradually increases at the unit of 1 mm/h, T_{BB} correlation coefficient goes down when the rain rate is less than 4 mm/h; the correlation goes up when the rate gets to or stays higher than 4

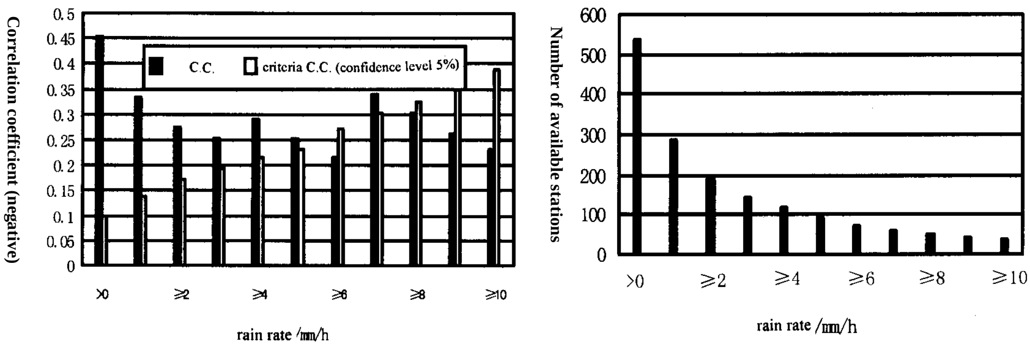

Fig.4 The distribution of Correlation Coefficient (C. C.) between rain rate of different degree and T_{BB} (left), and the numbers of available rainfall station (right).

mm/h, though reducing again afterwards. The correlation is less than the 95% confidence level once the rain rate ≥ 6 mm/h. It is especially interesting to note that the correlation coefficient increases significantly when the rain rate ≥ 7 mm/h, with the confidence level at 95%. It decreases to some degree, however, when the rain rate increases to 8 mm/h to 10 mm/h. In the meantime, the associated decrease of available rainfall records lead to a reduction of the confidence level to less than 95%. From our review of the variation of the rain rate correlation with T_{BB} at an increment of 1 mm/h, a general picture can be drawn that the TMI-85.5 GHz is a good detector of severe precipitation with additional capability of general judgement of whether or not precipitation have taken place.

4.3 *Correlation between rain rates of varying grades and* T_{BB}

To have deeper understanding of the relationship between the rain rate of varying grades and the T_{BB}, we divided the rain rate into 4 grades (Tab.2) for computation of coefficient of correlation at individual grades. As shown in Fig.5, the correlation is very small (–0.074) for weak precipitation at a rate of only 0.1 mm/h ~ 0.4 mm/h (Grade a); it is also quite small (–0.146) when the rate is between 0.5 mm/h and 2.9 mm/h (Grade b); it is still insignificantly large (–0.152) for the range from 3.0 mm/h to 6.9 mm/h (Grade c). They are all below the 95% confidence level. It is only for the rain rate ≥ 7mm/h (Grade d) that the correlation coefficient increases significantly to –0.338, with the confidence degree reaching 5% and confidence level 95%. From the distribution of coefficients of correlation between 4 grades of rain rate and T_{BB}, it is known that the increase of rain rate is accompanied with a rising trend of correlation coefficient and the rise amplitude is the maximum when the rain rate reaches 7 mm/h or more. It is an indication that the TMI-85.5 GHz is significantly good in measuring precipitation above 7 mm/h. Viewed from the point of cloud physics, the rain rate of stratiform cloud is seldom over 7 mm/h, which is basically a threshold for severe convective precipitation. It is also a reflection that the TMI-85.5 GHz is a poor microwave detector of mild and moderate precipitation but performs well for convective precipitation with extraordinarily high intensity.

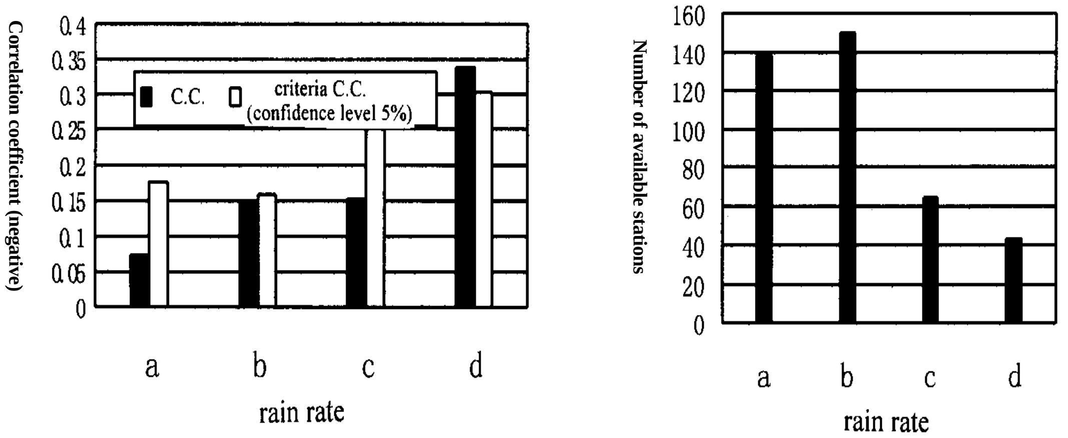

Fig.5 The distribution of Correlation Coefficient (C.C.) between rain rate of different class and T_{BB} (left) and the numbers of available rainfall record (right).

5 CONCLUDING REMARKS

Comparisons were made between the rainfall data during the South China Heavy Rain Experiment in the early and middle periods of June 1998 and the distribution of T_{BB} taken by TMI-85.5 GHz onboard the TRMM satellite for corresponding time levels. The result shows that the microwave at 85.5 GHz is a good detector of convective precipitation in the low-latitude area because the rain rate has a significant negative correlation with T_{BB}, as shown in relevant analysis. A statistical study of rain rates with varying grades and T_{BB} also shows that the microwave radiation at 85.5 GHz is especially sensitive to very large rainfall intensity, and it is a good detector of severe convective precipitation in the tropics.

Acknowledgements: Mr. CAO Chao-xiong, who works at the Guangzhou Institute of Tropical and Oceanic Meteorology, has translated the paper into English.

REFERENCES:

[1] JOANNE Simpson, ROBERT F Adler, GERALD R North. A proposed Tropical Rainfall Measuring Mission (TRMM) satellite [J]. *Bulletin of American Meteorological Society*, 1988, **69**: 278-295.
[2] ZHOU Xiu-ji, LU Da-ren, HUANG Run-heng, et al. Atmospheric Microwave Radiation and Principles of Remote-Sensing [M]. Beijing: Science Press, 1982. 46-48.
[3] MASON B J. Cloud Physics [M]. Translated by Atmospheric Physics Institute of Chinese Academy of Sciences. Beijing: Science Press, 1978. 325-341.
[4] TU Qi-pu, WANG Jun-de, DING Yu-guo, et al. Applied Probability Statistics in Meteorology [M]. Beijing: Meteorological Press, 1984. 102-147.