RAINFALL ESTIMATION OVER THE TAIWAN ISLAND FROM TRMM/TMI DATA DURING THE TYPHOON SEASON

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ABSTRACT:

A new algorithm for satellite microwave rainfall retrievals over the land of Taiwan using TMI (TRMM Microwave Imager) data on board TRMM (Tropical Rainfall Measuring Mission) satellite is described in this study. The scattering index method (Grody, 1991) was accepted to develop a rainfall estimation algorithm and the measurements from Automatic Rainfall and Meteorological Telemetry System (ARMTS) were employed to evaluate the satellite rainfall retrievals.

Based on the standard products of 2A25 derived from TRMM/PR data, the rainfall areas over Taiwan were divided into convective rainfall area and stratiform rainfall areas with/without bright band. The results of rainfall estimation from the division of rain type are compared with those without the division of rain type. It is shown that the mean rainfall difference for the convective rain type is reduced from -6.2mm/hr to 1.7mm/hr and for the stratiform rain type with bright band is decreased from 10.7 mm/hr to 2.1mm/hr. But it seems not significant improvement for the stratiform rain type without bright band.

KEY WORDS: TRMM, TMI, PR, ARMTS, SIL, convective, stratiform, bright band

1. INTRODUCTION

In Taiwan areas, the typhoon season usually takes place during the summer. The heavy rainfall accompanied with storm often causes mudslides on mountainous upstream areas, which could subsequently lead to serious silting in rivers and reservoirs. Therefore the rainfall estimation and the prevention of disaster from heavy rainfall become an important key issue for the community of meteorology. In this study, we use the formula of satellite rainfall estimation, which was created by Chen et al. (2005), to estimate the rainfall using TMI data. Though Chen et al. (2005) received reasonable results from their own formula; it seems that a much better result could be expected if the TMI pixels could be divided into convective and stratiform rain type. The aim of this paper is to try to improve the accuracy of the rainfall estimation over land associated with typhoons with the help of rain-type data from standard products (2A25) of the TRMM/PR. There are three kinds of rain type from 2A25: convective rainfall, stratiform rainfall with and without bright bands.

2. DATA COLLECTION

2.1 Satellite Data Collection

The data used in this study include the datasets from the TMI, VIRS and Precipitation Radar instruments of the TRMM satellite and the rain gauge data from ARMTS. In order to conduct different rainfall retrievals from TRMM/PR's different rainfall types, 13 typhoon cases that made landfall in Taiwan during 2001~2004 were selected and analyzed (shown in Table 1).

2.2 The Rain Gauge Data over Land

The collection of the rain gauge data is obtained from Taiwan's ARMTS, which can be found in the DBAR (Data Bank for Atmospheric Research) database of Department of Atmospheric Science, National Taiwan University. There are a total of 362 automatic rainfall observation stations scattered across Taiwan, shown in Fig. 1.

3. RAINFALL RETRIEVAL EQUATIONS OF TRMM/TMI FOR DIFFERENT RAINFALL TYPES

Based on the standard products of 2A25 derived from TRMM/PR data, the land rainfall are divided into convective rainfall and stratiform rainfall with and without bright bands. The TRMM/TMI microwave data corresponding to various rain types are separately collected to establish their relationships between TMI brightness temperatures and the amount of rain from gauge. Before the establishment of rainfall retrieval algorithms, a TMI data pre-processing was done for avoiding unexpected errors. The pre-processing includes the removal of incomplete beam-filling pixels and the pixels on the edges of swath of TRMM orbits.

Table 1. The 13 typhoon cases that were observed by the TRMM satellite when they made landfall in Taiwan.

Typhoon name	Date	Over TW Orbit No.	Typhoon name	Date	Over TW Orbit No.
CIMARON	2001/05/11	19883	LEKIMA	2001/09/24	22017
	2001/05/12	19894		2001/09/27	22067
CHEBI	2001/06/23	20558		2001/09/28	22078
UTOR	2001/07/04	20732		2001/09/28	22082
	2001/07/05	20743	RAMMASUN	2002/07/03	26413
TRAMI	2001/07/11	20840		2002/07/03	26417
TORAJI	2001/07/29	21129	SOUDELOR	2003/06/17	31851
	2001/07/30	21133	MELOR	2003/11/02	33999
NARI	2001/09/06	21731	MINDULLE	2004/06/30	37758
	2001/09/16	21895		2004/07/01	37769
	2001/09/17	21899		2004/07/01	37773
	2001/09/17	21910		2004/07/02	37785
	2001/09/17	21914		2004/07/02	37789
			AERE	2004/08/24	38609
				2004/08/24	38613

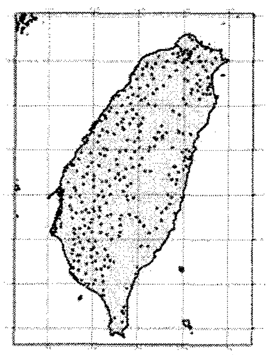

Fig. 1. The distribution map of the rainfall observation stations scattered over Taiwan

3.1 Convective rainfall retrieval equation

The 8K rainfall threshold of SIL (Chen et al., 2005) was used in this study. There are a total of 15 effective sample data collected for establishing the convective rainfall retrieval algorithm, shown in Fig. 2. The convective rainfall retrieval equation over the land area in Taiwan using a statistical regression method is shown as follows:

$$RR\ (mm/hr) = 0.012\ SIL^{1.918} \quad (1)$$

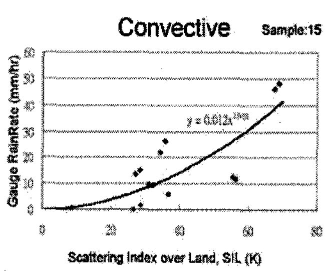

Fig.2. The scatter plot of SIL and rain rate and the fitting curve between them for the convective rain type.

3.2 Stratiform rainfall with Bright Band retrieval equation

Given the fact that ice particles in the air are considered a major scattering material, the SIL is primarily intended to detect the scattering level in the air and render it possible for an indirect retrieval of the land rainfall, which thus contributes to the study of stratiform rainfall retrievals with bright band. The ice content in the air will always affect the estimation of land rainfall via SIL. Based on 26 available samples, the relationship between the SIL value and observed rainfall from rain gauges was established by a statistical regression method and shown in Fig. 3.

$$RR\ (mm/hr) = 0.001\ SIL^{2.215} \quad (2)$$

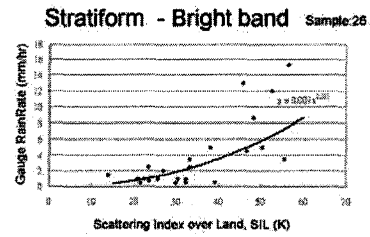

Fig. 3. The scatter plot of SIL and rain rate and the fitting curve between them for the stratiform rain type with bright band.

3.3 Rainfall Retrieval Equation of Stratiform Rainfall Area without Bright Band

There are two kinds of situations for the stratiform rain type without bright band: (1) shallow rain that is below the freezing layer and close to the ground surface; (2) possible stratiform rainfall with bright band, but the bright band isn't detected by TRMM/PR. Thus, the SIL value in this particular rainfall area is relatively small. However, there was some stratiform rainfall with bright band that weren't detected by the PR. Thus, the SIL values of these samples were much larger (over 20K).

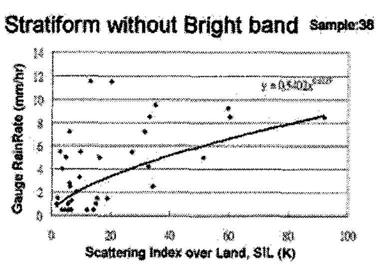

Fig. 4. The scatter plot of SIL and rain rate and the fitting curve between them for the stratiform rain type without bright band.

There are 38 samples collected from the stratiform rain type without bright band. The relationship between the SIL value and the observed rainfall from rain gauges is shown in Fig. 4. The rainfall retrieval equation is as follows:

$$RR\ (mm/hr) = 0.54\ SIL^{0.613} \qquad (3)$$

4. VALIDATION OF RAINFALL RETRIEVAL RESULTS

This section tries to validate the retrieval results of the land rainfall in Taiwan for the three kind of rain types. The comparisons between rain gauge (ARMTS_RR), rainfall estimation from Chen et. al.,(2005) (LRCT_RR), rainfall closest to the ground surface from 2A25 (PR_RR), and rainfall from this study for three kinds of rain type are shown in the Fig. 5-7, respectively. The convective rainfall estimation is with the symbol of TMI_CON_RR and the stratiform estimation with and without bright bands have the symbols of TMI_SBB_RR and TMI_SNB_RR. The statistical analysis is shown in Table 2. There are a total of 23 typical samples for convective case. In Fig. 5, it is shown that the rainfall of PR_RR is evidently overestimated, whereas the rainfall of LRCT_RR is clearly underestimated than that of rain gauge. The mean rainfall difference for LRCT_RR is -6.2 mm/hr and that of TMI_CON_RR is 1.7 mm/hr. It means that the division of TMI pixels for three kinds of rain type is with a positive impact on the improvement of rainfall estimation. But the difference of the RMS of TMI_CON_RR is larger than that of LRCT_RR.

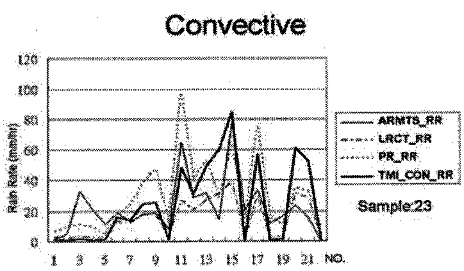

Fig. 5. The comparison of four kinds of rain rate for the convective rain type. The meaning of symbols is explained in the text.

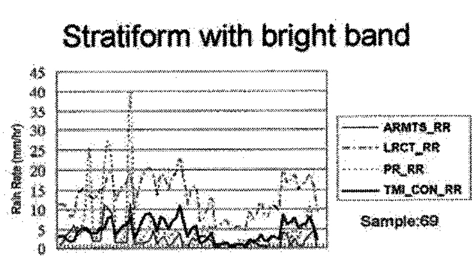

Fig. 6. The comparison of four kinds of rain rate for the stratiform rain type with bright band.

There are a total of 69 typical samples for the stratiform rain type with bright band. Fig. 6 indicates the rainfall of LRCT_RR is evidently overestimated, with a difference of about 10mm/hr. Moreover, there are 3 distinct points of the PR_RR that are greatly overestimated, with a maximum difference reaching 30mm/hr. However, the results of other samples do correspond to the land rainfall of the ARMTS_RR. The TMI_SBB_RR is closer to the observed land rainfall, which is consistent with the overall rainfall variations.

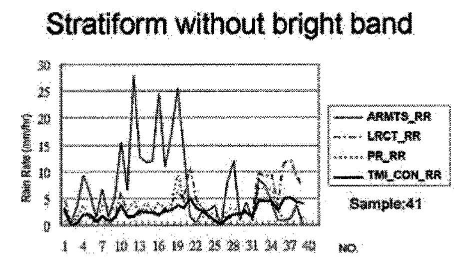

Fig. 7. The comparison of four kinds of rain rate for the stratiform rain type without bright band.

Table 2. The different results of the rainfall retrieval from ARMTS, LRCT and the PR rainfall rate for different rain types.

Retrieval Algorithm	Convective Rainfall Areas		Stratiform Rainfall Areas			
			With Bright Band		Without Bright Band	
	mean rain rate	RMS	mean rain rate	RMS	mean rain rate	RMS
Ground Truth	18.1	—	2.3	—	7.1	—
LRCT_RR	11.9	14.4	13.0	11.6	3.8	8.9
PR_RR	24.3	15.6	4.7	5.4	2.9	7.6
LRCT_RR*	19.8	17.5	4.4	3.4	2.6	8.6
LRCT_RR* represents the retrieval results under different rainfall types						

There are a total of 41 typical samples for the stratiform rainfall type without bright band: Fig. 7 indicates that the satellite-based rainfall of the LRCT_RR, PR_RR and TMI_SNB_RR correspond to each other, but vary considerably from the rainfall observations of ARMTS_RR, especially for the samples of ARMTS_RR which are over 10 mm/hr. The overall rainfall estimations of TMI_SNB_RR drop relatively, showing a bigger difference with the ARMTS_RR, but closer to the PR_RR. It can be witnessed that in the stratiform rainfall type without bright band, the mean rainfall PR_RR estimated from TRMM/PR and the mean rainfall LRCT_RR, TMI_SNB_RR estimated from TMI are both evidently underestimated, showing a higher RMS value. After the TMI rainfall retrieval is modified, the mean rainfall difference of the TMI_SNB_RR and ARMTS_RR is -4.5 mm/hr, which exhibits a bigger difference. If compared with the PR_RR, it is closer to the estimated rainfall of the PR, owning a mean rainfall difference of -0.3 mm/hr.

5. CONCLUSIONS

In the past, land rainfall estimation for convective rainfall areas were underestimated, while the stratiform rainfall areas were overestimated, due to the fact that previous studies on land rainfall retrieval did not take rain type into consideration. In order to improve the accuracy of the land rainfall estimation, rain type from TRMM/PR-2A25 standard products was introduced and rainfall type were divided into convective, stratiform with/without bright band. With the help of rain type, the mean rainfall error of the convective rainfall type is reduced from -6.2 mm/hr to 1.7 mm/hr, and the stratiform rainfall type with bright band is from 10.7 mm/hr to 2.1 mm/hr. It is found that the convective rainfall and stratiform rainfall with bright band significantly improved their accuracies, except for the case of the stratiform without bright band. This is because the rainfall type without bright band is comprised of shallow rain that is located below the freezing layer, as well as the possible existence of the bright band. Moreover, the stratiform rainfall with bright band could not be detected, leading to confusing results of the overall rainfall retrieval. This paper also shows that the SIL is not suitable for the indirect rainfall retrieval via the high-frequency scattering mechanism. The shallow rain near the surface should be further studied and developed in the future.

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