P1.20

# Over-ocean rainfall retrieval from TRMM/TMI data during the Typhoon season

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## 1. Introduction

Every year from July to October, the Taiwan area is to be affected by Typhoon and then produced heavy rainfall. The estimated rainfall rate of favorable method is used to utilize Microwave channels so far, because the microwave radiation can penetrate cloud and interact with the precipitation directly. Therefore, microwave channel is a desirable tool for estimating rainfall. The development of the satellite microwave remote sensing rainfall technique had considerable progress in the last two decades due to the satellite technology and the invention of new type instrument observing rainfalls recently.

In general, the estimated precipitation method is used to utilize microwave data to retrieve rainfall rate over ocean (Wilheit and Chang, 1991). The purpose in this study is to create the relationship between brightness temperatures and the rainfall rate (Tbs-RR) by using the multi-linear regressional technique and to retrieve the precipitation of typhoon.

## 2. Basic theory

The radiometer of spacecraft could be used to detect the oceanic rainfall, it is because that the microwave radiation has direct interactions with raindrop and ice within the rain cloud through emission, absorption and scattering processes when it passes through the rain cloud.

Under the assumption that the rainfall distribution is uniform within a FOV (Field of View), the Tb value will be increased with rainfall intensity and that the relationship between Tb and rainfall rate is linear. In addition, the saturation effect should be considered because when the rainfall is growing up to middle-, heavy-amounts, there will exist more greater size of raindrop and ice particles , which will decrease the Tb value by scattering process. Therefore, the low emissivity of the sea surface provides a colder background for detecting rainfall above ocean with relatively higher emissivity. The method is called emission rainfall algorithm.

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The scattering rainfall algorithms rely on the general cooling in the high-frequency channels due to the scattering of ice in the upper portions of many raining clouds. The radiation transfer processes of rain can be separated into two regimes: the attenuation regime and the scattering regime. The observed Tb of attenuation regime represents observations of the liquid hydrometer within rain cloud, which may be considered direct measurements of the rainfall. Oppositely, the observed Tb of scattering regime depends on the ice layer. The factors determining the type of attenuation encountered are the size of precipitation particle, the phase of the particle (ice or liquid), and the wavelength of the radiation (Kidd et al. 1998).

## 3. Data

(1) TRMM/TMI

TRMM satellite was launched in November of 1997 and its inclination is 35-degree. TMI scans the earth with a conical mode. It belongs to lower-altitude orbit (350 and 402 km before and after Aug. 2001) and its period is 92 minutes to circle the earth each time. The aim is to proceed with the tropical rainfall observation by using radiometer of TRMM which is a better implement for observing tropical rainfall. The spatial resolution is about 10 km after calibration.

(2)TRMM/VIRS

The Visible and Infrared Scanner (VIRS) onboard the TRMM satellite is a five-channel at the 1.61-micron band, and IR channels at the 3.75-, 11- and 12-micron bands. Among the observation data of TRMM satellite, we collect TMI microwave data and 10.8 μm infrared data of TRMM/VIRS for retrieving rainfall rate over ocean. The spatial resolution of VIRS Level-1B01 data used in this study is 2.2 km and its swath is 720 km. The merit of estimating rainfall using VIRS is to examine quality of TMI simultaneously.

(3)Rain gauge data

Island rain gauge data (mm/10-min) was received from Japan Meteorological Agency (JMA) and data range period is from July to October of 1998-2004. In this study, the rain gauge data were used as ground truth for satellite rain retrievals.

## 4. Algorithm

(1)Rainfall classification

The scattering index (SI) technique using the TMI for identifying oceanic rainfalls was used. SI technique originally developed for the SSM/I rainfall rate estimated technique for recognizing rainy scenes over ocean (Ferraro et al. 1994). The threshold check (TC) technique using no-rainfall of seven island rain gauges around Taiwan, the no-rainfall thresholds are the mean of no-rainfall statistics from the island rain gauges (Chen and Li 2000). For global applications, the SI value greater than 10 K indicates the presence of both scattering and emission owing to rain and generally association with rainfall rate of 1 mm/hr or greater. The TMI measurement whose Tb85V (Vertical) and Tb85H (Horizontal) are lower than their no-rainfall thresholds was classified as a rain scene associated with scattering-based mechanism due to the characteristics of these channels. Otherwise, a rainy case was associated with the attenuation-based mechanism.

Due to this research utilizes SI technique over ocean to classify the rainfall region of typhoon the effect of classification is favorable to this local experiment area. Although the SI technique of successful identification would be worse than TC technique to the rainy events, the SI of successful identification percent to no-rain events is up to 99%. The SI of average identification efficiency for recognizing rainfall observed by eleven island rain gauges within typhoon season from 2002 to 2004 is about 94% better than 63.5% of TC technique. This research adopts SI and TC techniques to classify the rainy region, in order to utilize the advantage of these two kind techniques that could be complementary after doing some adjustment. The SI and TC techniques of identification rainfall area have better results for classifying no-rainfall and rainfall, respectively. In this study, the combined method which was blended with SI and TC as a new method of identifying no-rainfall and rainfall is called CC (Combination Check) technique. The results of new technique classification are 99.4%, 100%, and 100%, respectively.

(2)Estimated quantitative rainfall

The multi-linear regression equations could be created by using 14 typhoons' data collected from 1998 to 2003 within the interest area (Table 1) for convective and stratiform rainfall type, respectively, The data sets were separated into convective rain type with 103 cases and stratiform rain type with 157 cases. The coefficient of determination ($R^2$) between Tb and RR are 0.52 and 0.25 for convective and stratiform rain types, respectively. It showed the result of convective type is better than that of stratiform type. It is because that most heavy rainfall cases are caused by convective rainfall type. The result of overall rainfall rate retrieval has fine behavior to retrieve the rainfall intensity and actual rainfall observed value.

In practical operation, the TMI data will be examined with supervised classification technique. If the island rain gauge is located closely to the edge of rain cloud, the observed rainfall rate will not be considered as the average rainfall rate actually within the FOV. The phenomenon will be called as beam-filling error (Kummerow, 1998). The flowchart of retrieving rainfall rate over ocean is shown as Figure 1.

## 5. Results

In this study, the 10-minute rain gauge data from eleven small islands' measurements, near IRABU of southern Japan, are used as the ground truth to validate the TMI estimated rainfall rate from June to October, 2004. There are 66 cases of matching between rain gauge and brightness temperature during 2004. The rainfall rates of 59 of the 66 cases are greater than 10 mm/hr, 4 of the 66 cases are between 10 to 20 mm/hr, and 3 of the 66 cases are between 20 to 30 mm/hr. The 66 sampling cases were separated into convective (25 cases) and stratiform (41 cases) rainfall type using TC technique. The correlation coefficient of convective type is 0.7, and that of stratiform type is 0.5. The overall correlation coefficient is 0.74 for all rainfall samples (Figure 2.).

The GPROF (Goddard Profiling Algorithm) 2A12 is the product of surface rainfall established by Kummerow et al. (2001), which could be compared with estimated rainfall rate of TMI. The rainfall area of MINDULLE typhoon (2004/07/01 0448 UTC) estimated from Figure 3. (a) (b) are about coincident as the rainfall rate is greater than 1 mm/hr. To compare with Figure 3. (a) 21°~22°N, 122°~123°E and Figure 3. (b), the former retrieval rainfall values are greater than latter. In addition, the rainfall area of Figure 3. 20°~21°N, 121°~122°E, the TMI rainfall rate estimated are smaller than the 2A12. The quantitative validation of TMI is better than 2A12 product. The correlation coefficient is 0.46 of comparing between the rain gauge data and 2A12 surface rainfall rate. The result retrieved will be improved the correction about surface rainfall rate of 2A12 within local area.

To compare TMI retrieved by Chen and Li (2000) during the Mei-Yu season with the ground truth simultaneously. The result showed Figure 3. (a) 21°~22°N, 122°~123°E of the TMI_RR are greater than the estimated rainfall rate using regression equation of Mei-Yu season (Figure 4.).

Furthmore, the area from 16.5°~18.5°N, 115°~120°E of Figure 4., the rainfall rates are mostly between 2 to 5 mm/hr, but the rainfall rates of Figure 3. (a) are mostly smaller than 1 mm/hr within the same area. Therefore, the regression equation created with different season is only suitable for particular weather system. From the qualitative observation, the lowest brightness temperature of infrared image of TRMM/VIRS will show the possible heavier rainfall rate regime, but it could not stand for the surface of ground rainfall rate strongest place definitely. (Figure 5.)

## 6. Conclusion

The results show that the overall rain pixel recognition rates are 99.4.0%, 100% and 100% for 2002-2004, respectively. In validation, the rain gauge is regarded as ground truth. It showed that the Root-Mean-Square error of the satellite rainfall retrieval is 3.75 mm/hr and the coefficient of correlation between them is 0.74. It also shows that the satellite rainfall retrieval is overestimated for weak precipitation system and underestimated for severe precipitation system. The possible reason for this situation is possibly caused by beam-filling problem of the field of view. Therefore, the high resolution infrared channel data of TRMM/VIRS were used in this study to reduce the beam-filling problem and RMS error. The standard satellite rainfall retrievals, 2A12, of GPROF, retrieved by physical method and the regression satellite rainfall retrievals by Chen and Li (2000) are also compared with our results and the comparison shows that our algorithm is better than the above two results. The GPROF method was proved suitable for global scale only but not for regional one. In addition, the regression relationship obtained from a certain season data can't be extended to another season. For this reason, it is necessary for us to develop a new relationship between the satellite data and rain gauge for the Typhoon case. AMSR-E (Advanced Microwave Scanning Radiometer- EOS) of AQUA satellite and AMSU (Advanced Microwave Sounding Unit) data of NOAA satellite are planning to be included in our algorithm for improving the temporal and spatial resolutions and raise the operational usage of satellite rainfall retrievals.

The tendency of ground validation is to combine the rain gauge data effectively with the radar data as the ground truth (Seo, 1998) and to obtain the distribution of raindrop size and liquid water content in the future (Kummerow, 2001). Therefore, the research will be discussed with the principle of microphysical rainfall mechanism in the future. The research result in this study will be accurate and greatest help for meteorology remote sensing technique.

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Table 1. The regression equations of estimated convective and stratiform rainfall by using statistics.

| **Rain Type** | **Regression Equation** | **Correlation Coefficient (R)** |
|---|---|---|
| Convective precipitation | RR=152.65-0.77*Tb1+0.47*Tb2-0.147*Tb3+0.537*Tb4 -0.508*Tb5+0.818*Tb6-0.773*Tb7-0.91*Tb8+0.803*Tb9 | 0.85 |
| Stratiform precipitation | RR=-44.28-0.107*Tb1+0.06*Tb2+0.7*Tb3-0.15*Tb4 -0.308*Tb5+0.148*Tb6-0.15*Tb7-0.17*Tb8+0.18*Tb9 | 0.5 |

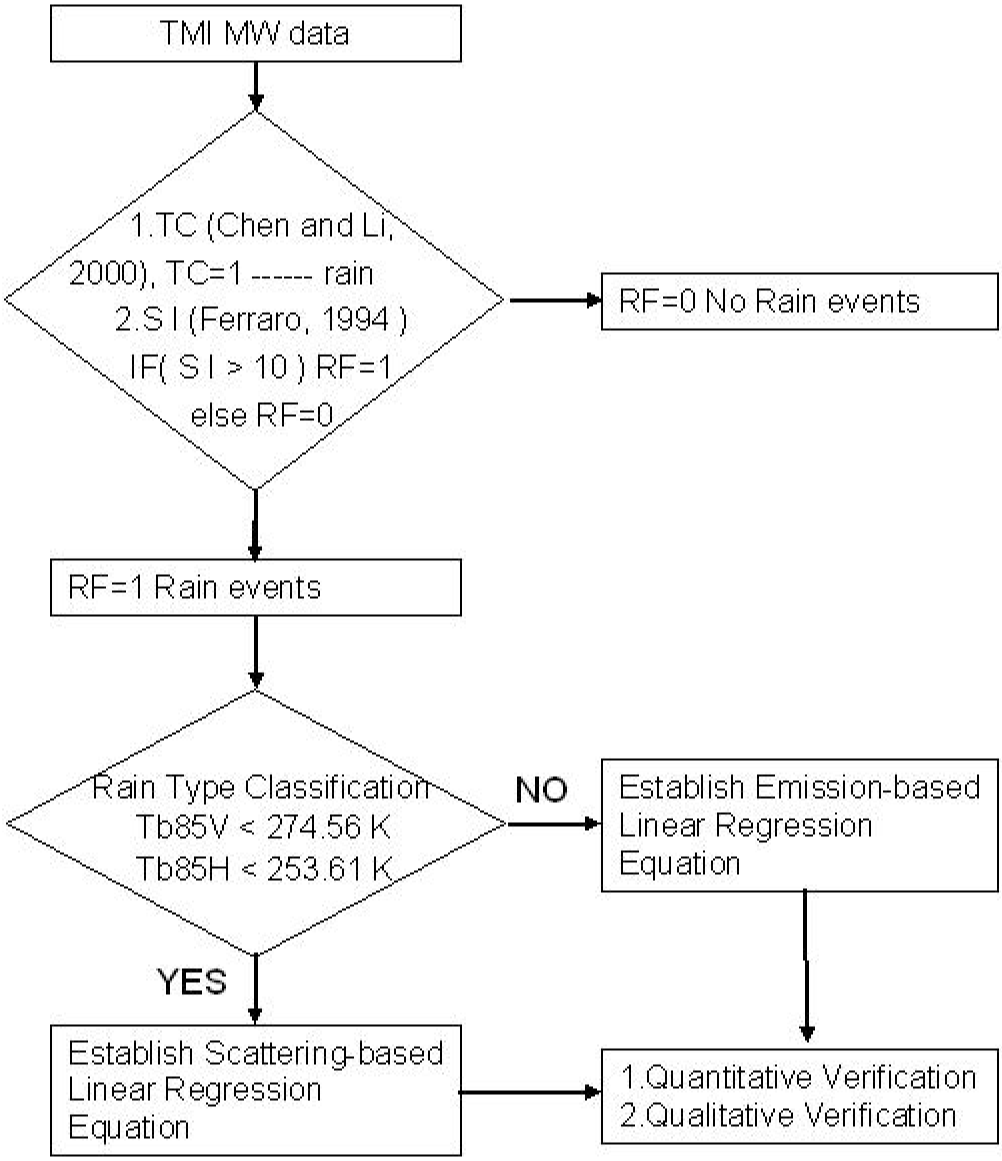


Figure 1. The flowchart of retrieval rainfall rate over ocean by using TMI data.

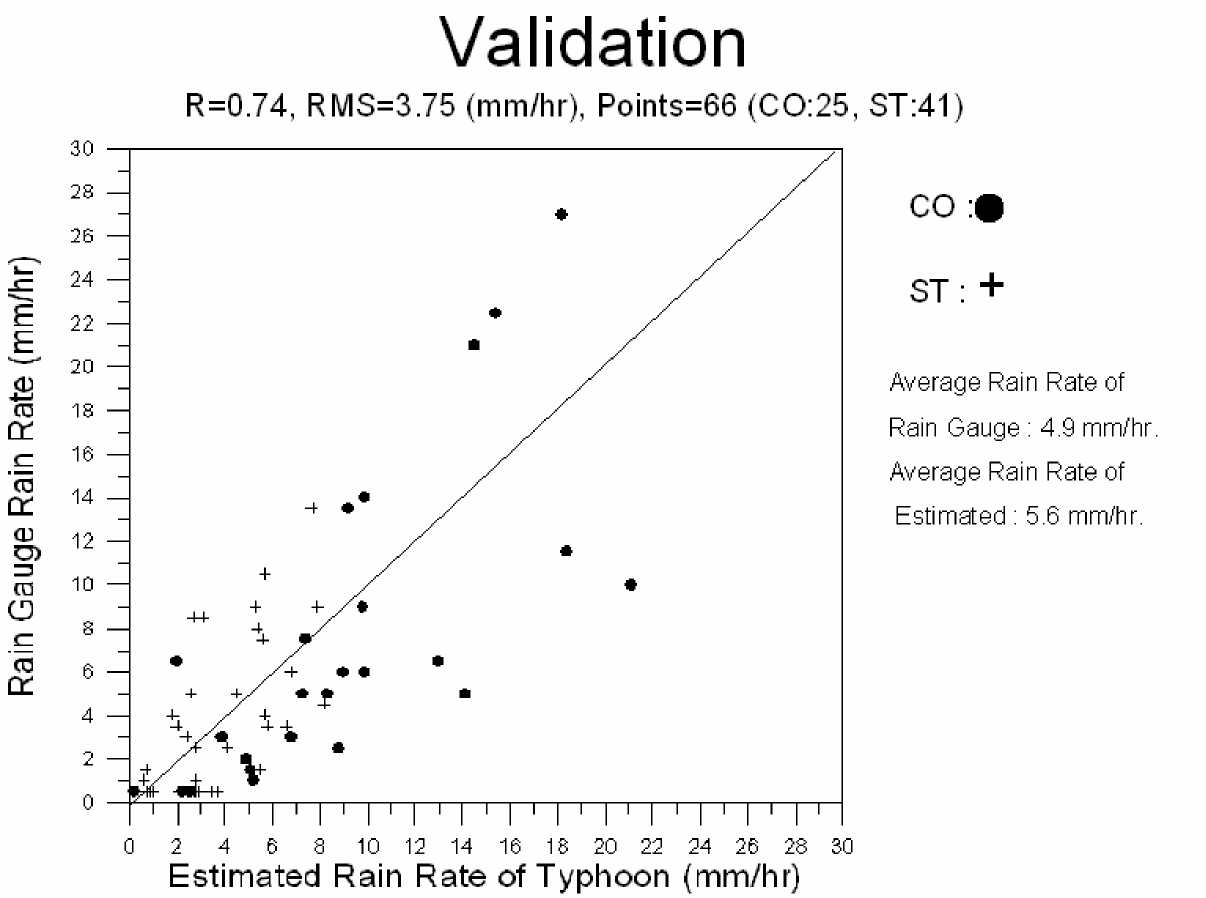


Figure 2. The TMI_RR retrievals and observed RR show the quantitative verification of the rain retrieval algorithm. The rain gauge hourly data were used as ground-based validation data. The correlation coefficient is 0.74 and the root mean square is 3.75 mm/hr. (CO: convective, ST: stratiform)

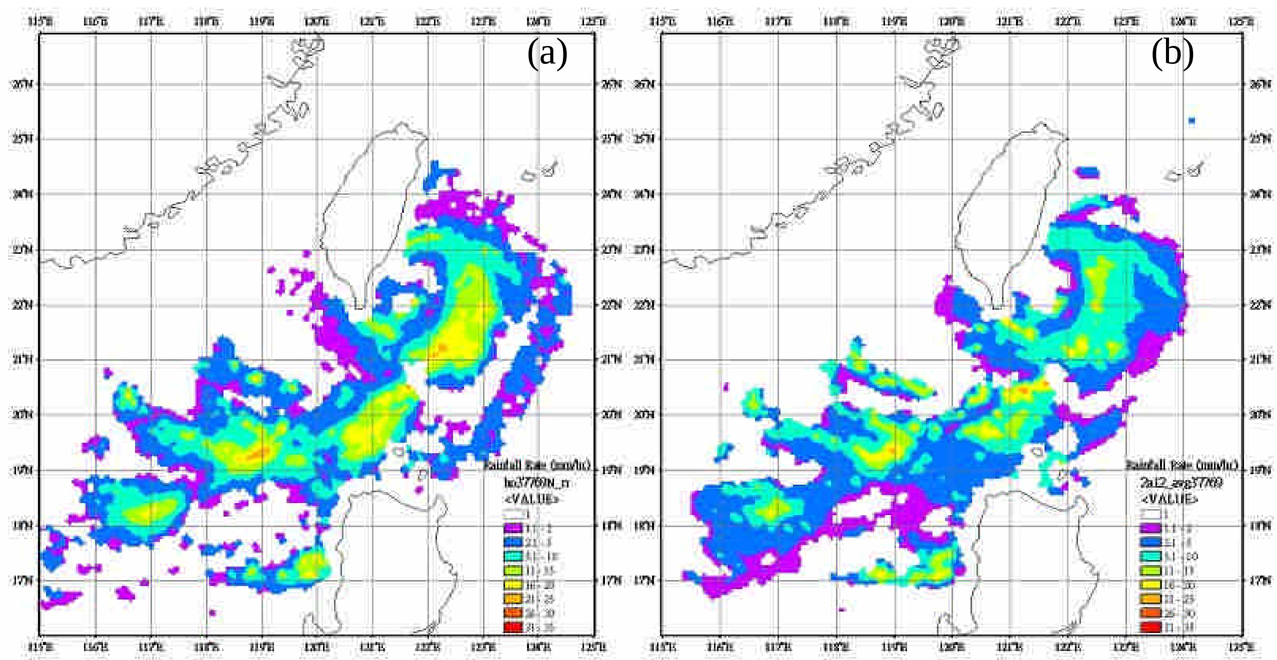


Figure 3. (a)The rain map of estimated rainfall rate of MINDULLE (2004/07/01 0448 UTC), (b)The rain map of using GPROF method to estimate rainfall rate over ocean, the time is same with (a).

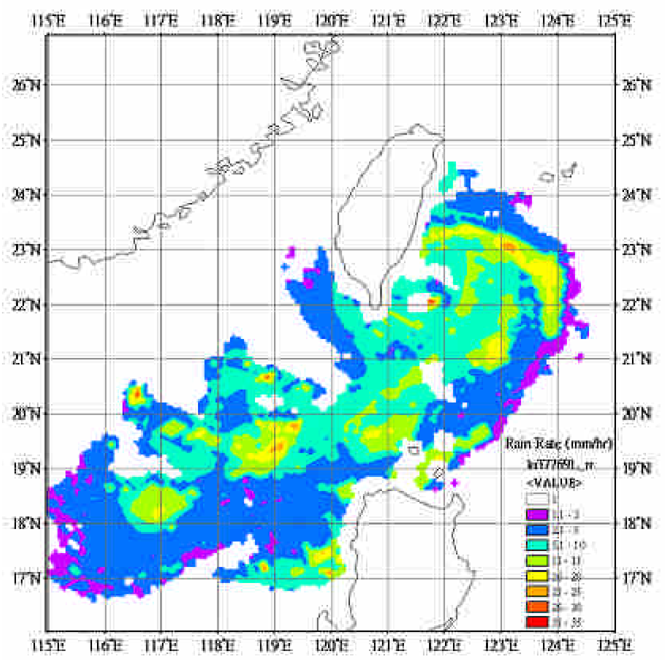


Figure 4. as same with Figure 3. The rain map is created by algorithm of Chen and Li over ocean during Mei-Yu season (2004/07/01 0448 UTC).

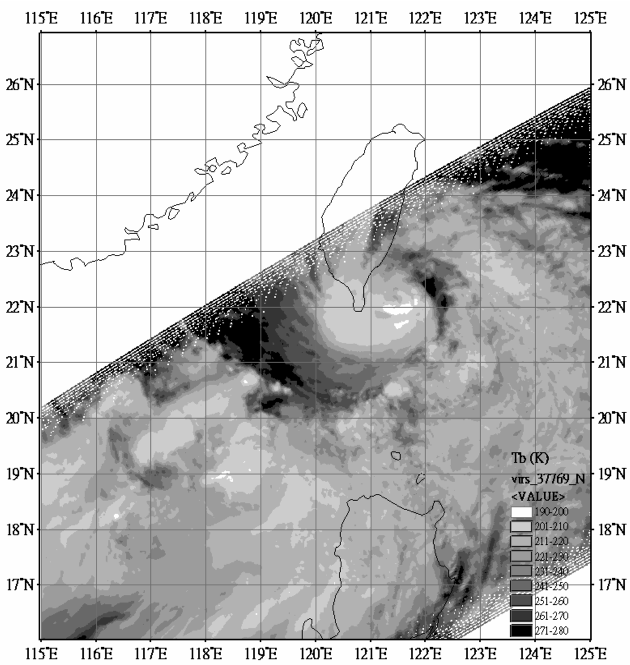


Figure 5. The image of infrared TRMM/VIRS 11μm (2004/07/01 0448 UTC).