APPLICATIONS OF SATELLITE PASSIVE MICROWAVE DATA TO RAINFALL ESTIMATION AND FOG DETECTION

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ABSTRACT:

The torrential rainfall from typhoon caused the damage and loss of lives and properties. The low visibility produced by heavy fog always has a significant impact on transportation and military mission. The above-mentioned atmospheric parameters are the requirements of operational organizations. The aim of this study is rainfall estimation and fog detection by passive microwave data.

Satellite passive microwave observations have potential to provide rainfall estimation and fog detection for wide oceans. The rainfall estimation for typhoons over ocean is using Bayesian approach. The fog detection over sea is based on the difference of brightness temperatures of TMI channels between heavy fog and clear weather conditions. The preliminary analysis shows the difference of brightness temperature is obvious in high frequency channels, especially in 85 GHz. In addition, we compare retrieved rain rate with that obtained from Precipitation Radar. Their correlation coefficients are 0.68 and 0.75 for the convection and stratiform rainfall patterns, respectively.

1. INTRODUCTION

The time span, spatial distribution, and the amount of precipitation have always been deeply concerned with human life. It is also closely relative to global energy transportation, atmosphere circulation, and climate change. The precipitation estimation from satellite remote observation recovers the shortage in space. The satellite microwave observations are now widely used to retrieve surface rain rate, because the microwave is not influenced by clouds (Adler et al. 2001).

In addition to the rainfall, the low visibility produced by fog has a significant impact on road transportation, aircraft launching and landing, vessel transportation and military mission et al.. Such impacts which mentioned above will cause economic loss (Mohan and Payra, 2009). The main purposes of this study are to detect the fog and rain rate retrieval from TMI observation.

2. METHODOLOGY

2.1 Rainfall estimation using Bayesian approach

A lot of rain rate retrieval methods were developed based on the Bayes' theorem methods (Marzano et al. 2002; Di Michele et al. 2005; Chiu and Petty 2006; Grecu and Olson 2006). At first a prior probability distribution ($f(R)$) was obtained by observations, then a conditional probability distribution ($f(P|R)$) was derived by microwave radiative transfer models (RTM), finally a posterior probability distribution of rainfall ($f(R|P)$) was calculated by combining a prior probability distribution and conditional probability distribution. In 1994, Petty brought up a suggestion that attenuation index P as the observed variable to reduce retrieval ambiguity. The P index is defined as

$$P \equiv \frac{T_V - T_H}{T_{V,O} - T_{H,O}}$$

Where T_V and T_H are vertical and horizontal polarization of TB; $T_{V,O}$ and $T_{H,O}$ are the TB observations in the clear condition. For simulations, back-ground brightness temperatures can be calculated by simply setting all hydrometeors to be zero. Figure 1 is the flowchart of this research method.

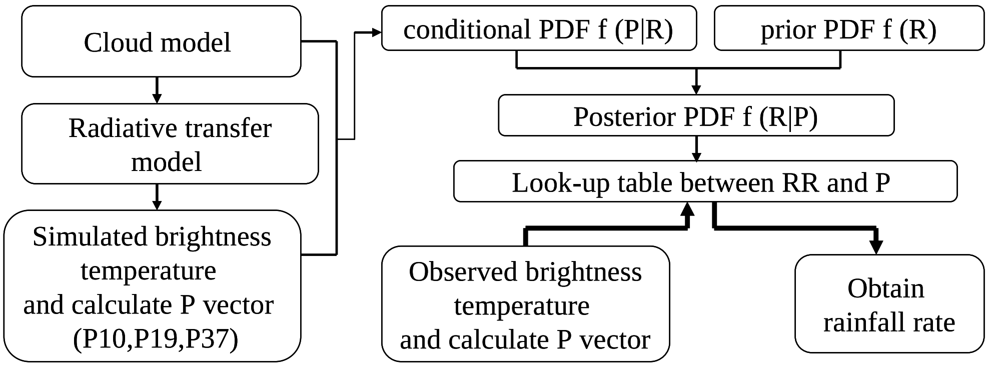

Figure 1. The flowchart of the Bayesian method

2.2 Research processing of fog detection

The flowchart is given in Figure 2 to summarize research method. Our proposed research process of fog detection contains the following four steps: The first step is selecting fog cases and recognizing fog areas. The second step is removing the land data and calculating the statistics of TMI TB. The third step is establishing the Tb criteria of fog. The final step is verifying with independent cases.

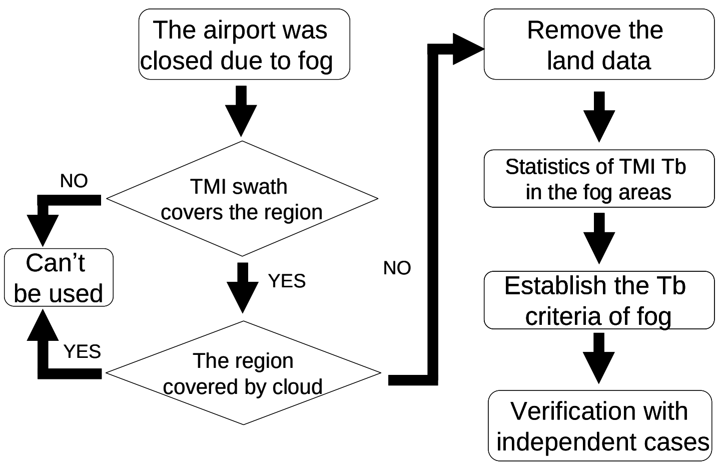

Figure 2. Research process flow chart for fog detection

3. RESULTS AND DISCUSSIONS

3.1 Validation of rainfall estimates

Retrieved rain rate is validated both in qualitative and quantitative aspects. First, we present qualitative comparison of horizontal structures from one overpass of Typhoon Morakot. This comparison was conducted mainly against PR-retrieved rain rate. Second, we present quantitative comparisons against PR-retrieved rain rate for three overpasses of typhoon Morakot (Figure 3).

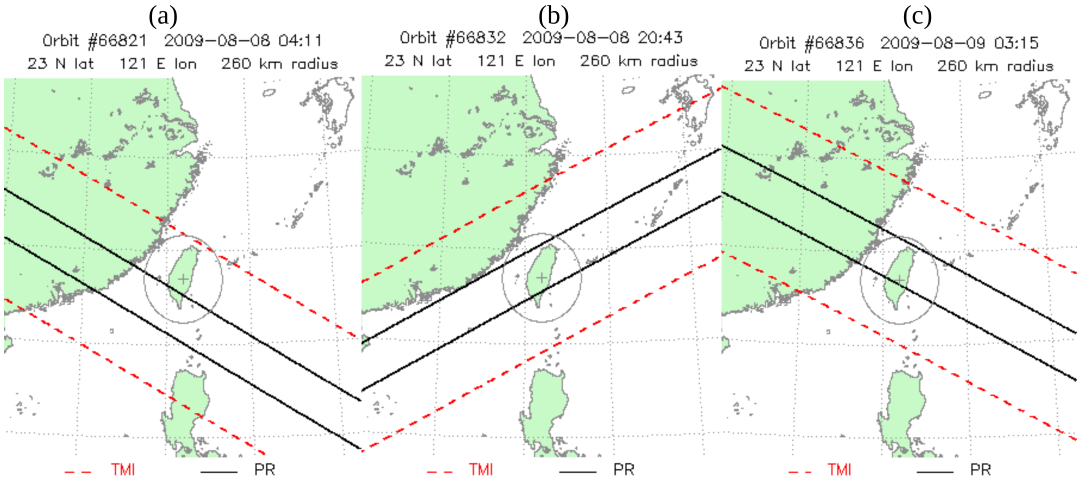

Figure 3. The swath of TRMM/TMI (red dash line) and of TRMM/PR (black solid line). (a) 2009/08/08 0411 UTC; (b) 2009/08/08 2043 UTC; (c) 2009/08/09 0315 UTC.

Figure 4(a) and Figure 4(b) show retrieved rain rate distribution of Typhoon Morakot from PR, and from the retrieval method of Bayesian approach respectively. In Fig. 4(a) of the PR rain map, the main heavy rain area is seen between the south of the Taiwan Straits (21°N, 118°E) and Bashi Channel (21°N, 120°E). Fig. 4(b) shows that the retrieved precipitation distributions are similar to PR rain map, although the retrieval rainfalls underestimate for the most heavy rain area.

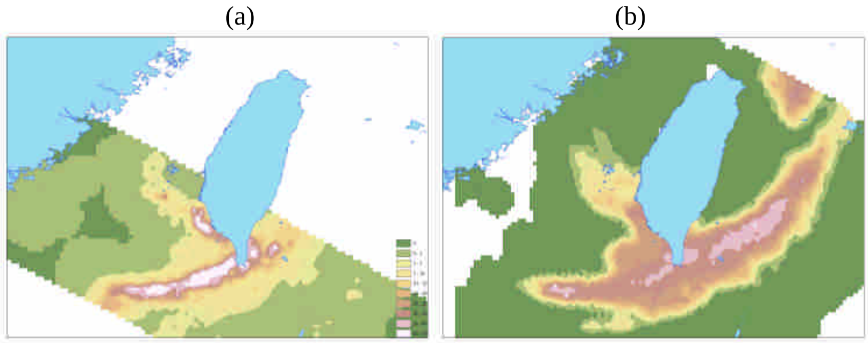

Figure 4. The rain rate of Typhoon Morakot retrieved from (a) PR; (b) Bayesian approach at 0411 on 08 August 2009.

Figure 5 shows scatter plots of retrieved rain rate versus PR measurements. The method tend to overestimate in light rain rate regimes and underestimate in heavy rain rate regimes, as is a typical drawback for a linear statistical retrieval method.

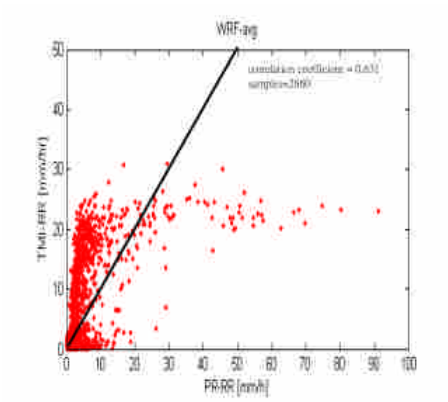

Figure 5. Scatter plots of retrieved rain rate versus PR measurements. Coefficients of determination and total samples of three passes are also shown here.

3.2 Verification with independent cases

The first case is fog condition of orbit number 63921, and its scanning time is 0238 UTC on February 3, 2009. The circles in Fig. 6 represent the Field of View (FOV) of TMI. The circle with dark red means heavy fog, and the circle with light red means light fog. The fog concentration is decide by integrated precipitable water vapor (IPWV) content which obtained by microwave data from TMI.

Fig. 6(a) meets more than one criterion, and Fig. 6(b)~6(d) meet more than two, three, and four criteria respectively. There is evidence in plenty to show that a significant sea fog area from northeast to southwest in the Taiwan Strait. Compare with the satellite IR and VIS image of 0300 UTC, February 3, 2009 (Fig. 7). The distribution of fog in our research is very similar to the distribution of fog in satellite image.

The ground station observations from Beigan airport show the visibility is 400 meters only. Although the observations from Magong airport show the visibility is more than 9999 meters, the result of our research (Fig. 6) indicates the fog area not cover the Magong airport.

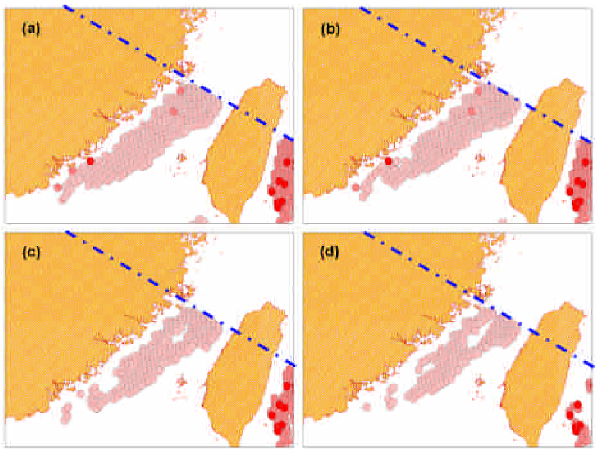

Figure 6.The figures meet more than (a)1, (b)2, (c)3, (d)4 criteria.
Blue dash line delineates the edge of swath, and the purple circles indicate FOV of TMI.

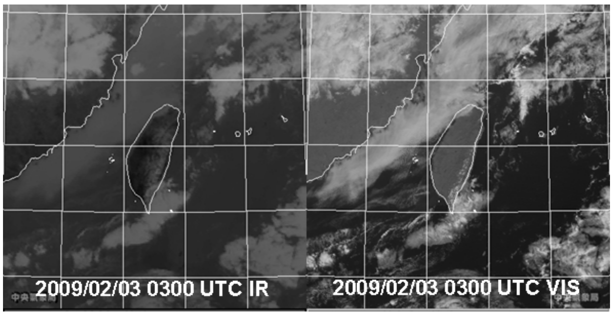

Figure 7 MTSAT-1R satellite images on Feb. 03, 2009 at 0300 UTC (left): IR, (right): VIS.

4. CONCLUSIONS

The Bayesian approach was accepted in this study to retrieve rain rate over ocean using TRMM/TMI microwave brightness temperatures, with an emphasis on typhoon Morakot. In addition, an attenuation index as the observed variable was used in our method, because it has a monotonic relationship with rain rate, and is less influenced to water vapor, wind speed and sea surface temperature and so on.

There are three overpasses of TRMM satellite for Typhoon Morakot as case studies. The results show that the Bayesian retrievals and PR rain rate show significant similarity in horizontal distribution of precipitation, and the correlation coefficient between them is above 0.6.

In addition, several finding are concluded from the study of fog detection: The first one is the microwave data can be used to detect fog over oceans during day and night, rather than IR and VIS have limitation in the time. The second one is not only to detect the location of the fog, but also determine the concentration of fog by IPWV. The third one is the 85-GHz horizontal polarization is the most sensitive to the fog

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