Infrared Rainfall Estimates Using the Probability Matching Method Applied to Coincident SSM/I and GMS-5 Data

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Abstract

Relations between GMS-5 infrared brightness temperature with SSM/I retrieved rain rate are determined by a probability matching method similar to Atlas et al. and Crosson et al. For this study, coincident data sets of the GMS-5 infrared measurements and SSM/I data during two summer seasons of 1997 and 1998 are constructed. The cumulative density functions (CDFs) of infrared brightness temperature and rain rate are matched at pairs of two variables which give the same percentile contribution.

The method was applied for estimating rain rate on 31 July 1998, examining heavy rainfall estimation of a flash flood event over Mt. Jiri. Results were compared with surface gauge observations run by Korean Meteorological Administration. It was noted that the method produced reasonably good quality of rain estimate, however, there was large area giving false rain due to the anvil type clouds surrounding deep convective clouds. Extensive validation against surface rain observation is currently under investigation.

1. Introduction

Heavy rain accompanied by meteorological phenomena like typhoon and Chang-ma is the most severe natural disaster in Korean Peninsula (KMA, 1995). Because of short process of heavy rain, the nowcasting technique is needed for its prediction.

For the purpose of the pertinent nowcasting of heavy rain, the satellite observations can overcome the difficulty in absence of ground measurements network by monitoring of rain band (Barrett and Martin, 1981). Infrared and microwave are generally used for rainrate estimation based on data of satellite observation (Kidder and Vonder Haar, 1995). Because we can get the thermal information on top of cloud from infrared data, infrared method which connects height or shape of cloud with rainrate and rain area, is regarded as indirect rainrate estimation method, on the other hand microwave method which uses characteristics of microwave, scattering and emission in going through rain layer, is regarded as more direct and physical method than infrared method. Therefore, it is the idealized approach which can get the such quality of rainrate estimated by microwave data from geostationary satellite data with outstanding temporal and spatial resolution.

In this study, we use coincident data sets of GMS-5 and SSM/I microwave data in order to improve nowcasting capability by using satellite data by retrieving rainrate from real time infrared data..

There are three channels in GMS-5 infrared data (water vapor: 6.5-7.0 ㎛, two window channels: 10.5-11.5 ㎛, 11.5-12.5 ㎛). By constructing coincident infrared data with SSM/I rain data, we develop rainrate estimation algorithm which cam retrieve rainrate from GMS-5 brightness temperature by applying probability matching method (PMM).

The produced rainrate distributions based on the developed algorithm is compared with those from automatic weather station (AWS) observations for the validation. The obtained results will be used as basic tool in the satellite-based rainfall nowcasting over the Korean Peninsula.

2. Data and Method

Coincident data sets of the GMS-5 infrared measurements and SSM/I microwave brightness temperature data during two summer seasons of 1996 and 1997 (June, July, and August, respectively) are constructed. The analysis domain is over East Asian from 22.5N to 47.5N and from 115E to 140E.

2.1 SSM/I Rain Rate

For creating the relationship of rainfall with the GMS-5 infrared measurements, we retrieve rainrate from SSM/I data by using the method by Ferraro *et al.* (1995).

$$R_L = 0.00513 \cdot SI^{1.9468}$$
$$R_O = 0.00115 \cdot SI^{2.16832} \qquad (1)$$

R_L and R_O are rainrates of land and ocean respectively, and SI (scattering index) indicates the degree of scattering of hydrological particles in the cloud at 85GHz.

2.2. Probability Matching Method (PMM)

We use PMM by Atlas *et al.* (1990) to connect the GMS-5 brightness temperature data with retrieved SSM/I rain rate.

$$\frac{\int_{R_r}^{R_i} RP(R)\,dR}{\int_{R_r}^{\infty} RP(R)\,dR} = \frac{\int_{TB_r}^{TB_i} TB\,P(TB)\,dTB}{\int_{TB_r}^{\infty} TB\,P(TB)\,dTB} \qquad (2)$$

P(R) and P(TB) are the probability density functions (PDF) of rainrate based on SSM/I measurements and GMS-5 infrared brightness temperature, respectively.

3. Results

From (2), we can find pairs (TB_i , R_i) which have the same PDFs of rainrate and brightness temperature. Therefore, by finding matched value between CDFs (cumulative distribution functions), we obtain relationship between brightness temperature and rainrate, RR = f(TB).

Fig. 1. shows that the method using CDF of TB11 describes well comparatively weak rainrate. In the other side because of relatively sparse data points, CDFs of TB11-6.7 are used for supplementing rain estimation for intense cases.

In this study, first, we develop algorithm by using only TB11 data (PMM1), second, we combine PMM1 algorithm with TB11-6.7 data (PMM2).

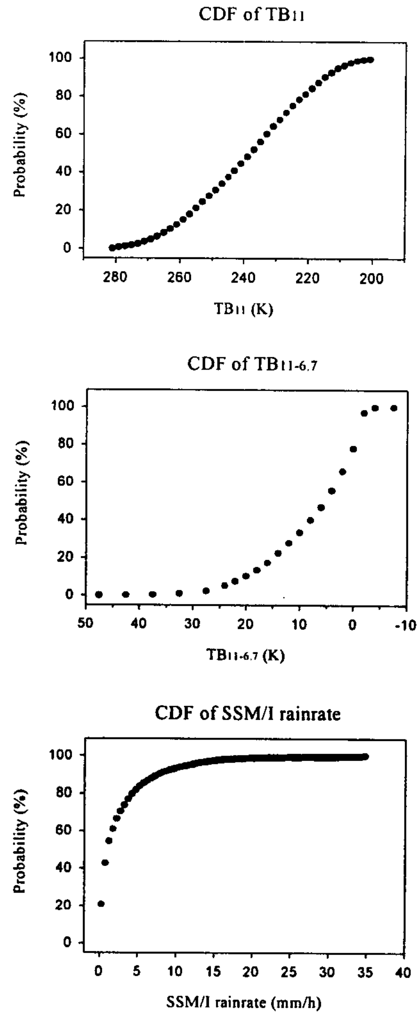

Fig. 1. Cumulative distribution functions of TB11, TB11-6.7, and SSM/I rainrate

3.1 PMM1

From constructed coincident data sets of GMS-5 TB11 (11㎛) and SSM/I rainrate, we obtain rainrate estimation equation as expressed by:

Rain = exp(-0.0820 * (TB11- 241.6786)) (3)

The unit of rain and TB11 are mm/hr, K respectively.

3.2 PMM2

By using TB11, TB11-6.7 of GMS-5 data and SSM/I rainrate, we obtain another rain estimation equations as below (S2 = TB11-TB11-6.7),

i) IR1 > 212.4 K: Rain = exp(-0.0820 * (TB11 - 241.6786))

ii) IR1 $\leq$ 212.4 K and S2 $\leq$ -0.42 K: Rain = exp(-0.2283 * (S2 - 10.6792)) (4)

iii) IR1 $\leq$ 212.4 K and S2 $\geq$ -0.42 K: Rain = 12.5

i), ii), iii) mean order of process. Accordingly, if any process is satisfied, the next processes are ignored.

3.3 Calculating rain area and rain rate

For the case of Mt. Jiri area where the heavy rain occurred at 1530 UTC 31 July 1998, we produced rain image by PMM1 and PMM2, respectively (Fig. 2 and3). In order to examine how the PMM algorithms perform, the results are compared with rain gauge observations at AWS sites (Fig. 4).

4. Conclusion

Developing an algorithm to calculate rain area and rainrate can be helpful for improvement of prediction such as heavy rain estimation for prevention of disasters. However, there are intrinsic problems of rainrate retrieval by infrared method indicating that the light rainfall area by AWS is to be the heavy rainfall area because of cirrus type clouds by PMM. Thus, more cases and qualitative analysis for long time should be required and currently under investigation.

5. References

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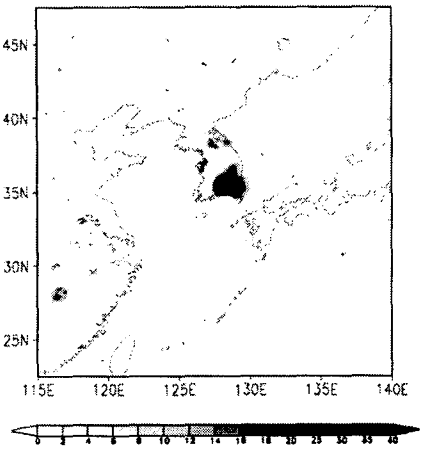

Fig. 2. Rainfall estimated by PMM1 for 1530 UTC on 31 July.

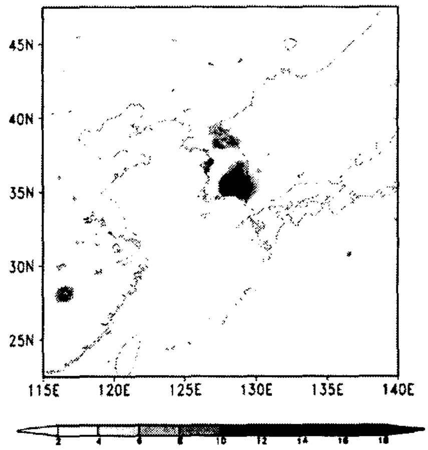

Fig. 3. Rainfall estimated by PMM2 for 1530 UTC on 31 July.

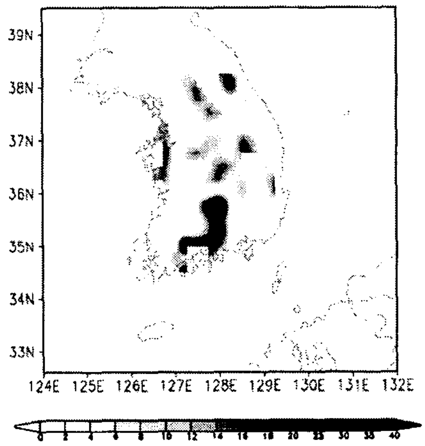

Fig. 4. Rainfall estimated by AWS for 1530 UTC on 31 July