MEASUREMENTS OF RAIN RATE DISTRIBUTION BY MOS-1 MSR

Yuji OHSAKI Masaharu FUJITA
Communications Research Laboratory
Ministry of Posts & Telecommunications

INTRODUCTION

Satellite observations are attractive for global monitoring of rain, the information of which is essential for investigating the environmental conditions of the earth. Feasibility of microwave remote sensing of rain with MSR (Microwave Scanning Radiometer) has been examined as a part of MOS-1 (Marine Observation Satellite-1) Verification Program by NASDA (National Space Development Agency of Japan). In this article, the comparison between MSR and ground-based radar measurements is described on the basis of the theory and experiment.

MSR AND RADAR DESCRIPTION

MOS-1 is the first remote sensing satellite of Japan. MSR carried on MOS-1 is a dual-frequency microwave radiometer operating at 23.8GHz and 31.4GHz. The polarizations of these bands are linear and mutually orthogonal. The polarization planes rotate with conical beam scanning. Since off-nadir angle of the MSR beam is 10 degrees (the incident angle to the earth's surface is 11.4 degrees), the variation of the brightness temperature due to the beam rotation is not so pronounced (2-3 K) even for a highly polaried surface (e.g., ocean surface). The MSR FOV (field of view) are 32km and 23km at the frequencies of 23.8GHz and 31.4GHz, respectively. The measurement of brightness temperature has the absolute accuracy with ± 2.0K in both bands for the integration time of 47msec.

The radar data used in the present comparative study is routinely measured by the S-band weather radar of JMA (Japan Meteorological Agency) installed on the top of Mt. Fuji. It operates with three elevation angles, i.e., -1.6, -1.0 and -0.5 degrees, to observe the rain over the earth's surface in the 1000 km square area. The original radar reflectivity factor Z digitized in 8 bits is used in this article, and the pixel size of the data is 2.5 km by 2.5 km. Based on a commonly used empirical relationship between Z and rain rate R, $Z=200R^{1.6}$ [Battan, 1973], the observed value of Z is converted to rain rate.

RAIN RATE ESTIMATION BY MSR

A theoretical calculation [Fujita and Miyagawa, 1987] for relating microwave brightness temperature measured with MSR to rain rate over the ocean was previously developed on the basis of the equation of radiative transfer. This calculation is based on the spatial homogeneous rain model. U.S. standard atmosphere and aerological data measured by JMA are used to construct the model, and the influences of molecular oxygen, water vapor, cloud water droplets and the ocean surface roughness are taken into account in the calculations. The equation of radiative transfer is numerically solved in order to take the influence of microwave scattering caused by rain drops into account. Figure 1 shows the theoretical relationship (solid curve) between brightness temperature at 31.4GHz and rain rate. This theoretically calculated curve cannot be expressed in the analytical formula, so that an approximate formula to obtain the rain rate from measured brightness temperature is derived based on the theoretically calculated curve. This approximate curve (dashed curve) is also shown in Figure 1.

DATA ANALYSIS

Figure 2 shows a comparison of the brightness temperature map observed by MSR and the rain rate map observed by the Mt. Fuji radar on 20 July 1987. High brightness temperature areas observed over the ocean at both MSR frequencies correspond to the rain areas identified by the radar.

In Figure 3, the values of the MSR brightness temperature at 31.4GHz are plotted against the radar-derived rain rates. The solid line represents the approximate curve as derived in Figure 1. In the comparison, the radar rain rates of 2.5km by 2.5km pixel are averaged over the MSR FOV. The theoretical estimation explains well the tendency of the experimental result.

Figure 4 shows the scatter diagram between the rain rates estimated from the MSR brightness temperature data at 31.4GHz based on the approximate curve shown in Figure 3 and the radar-derived rain rates averaged over the MSR FOV. The correlation coefficient of this scatter diagram is 0.66. This scatter diagram reveals that the MSR rain rates are lower than the averaged radar rain rates. The relationship between brightness temperature and rain rate is generally nonlinear and the MSR FOV is larger than typical rain cell size. Therefore, the rain rates estimated from the MSR brightness temperature are not equal to the actual rain rates averaged over the MSR FOV.

For estimating the error caused by the non-uniform distribution of rain in the MSR FOV, the equivalent brightness temperature is calculated from the radar rain data based on the approximate curve shown in Figure 3, and is compared with the MSR brightness temperature at 31.4GHz in Figure 5. The better value of correlation coefficient (0.70) is obtained.

CONCLUSIONS

The MSR brightness temperature has been related to the radar-derived rain rates, indicating a promising feature of the microwave remote sensing of rain. However, scatter in comparison between the rain rates derived form the MSR brightness temperature and from the radar measurements is considerable. This may partly be attributable to the non-uniform distribution of rain in the MSR FOV. Other than this, there can be various possible causes of the scatter; simplified assumptions used in the theory concerning rain and atmospheric models, etc., and also variability of Z-R relation. The error in registering the MSR brightness temperature map to the radar-derived rain rate map may be another possible cause.

The theoretical relationship in Figure 1 shows the saturation of brightness temperature at the range of high intensity of rain rate. Unfortunately in the case of this study, the strongly increased brightness temperature caused by the higher rain rates is not measured. But to clarify the performance of the theoretical calculation, it is necessary to investigate the relationship between the brightness temperature and the rain rates at the neighbourhood of the saturation on the theoretical relationship.

ACKNOWLEDGMENT

The authors would like to express their thanks to Mr. A. Shibata of the Meteorological Research Institute for providing Mt. Fuji radar data. This study has been done for the MOS-1 Verification Program conducted by NASDA.

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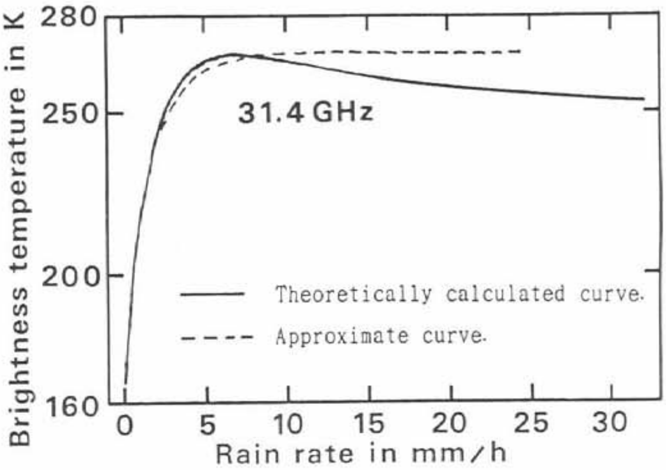

Figure 1. The theoretical relationship between brightness temperature at 31.4GHz and rain rate.

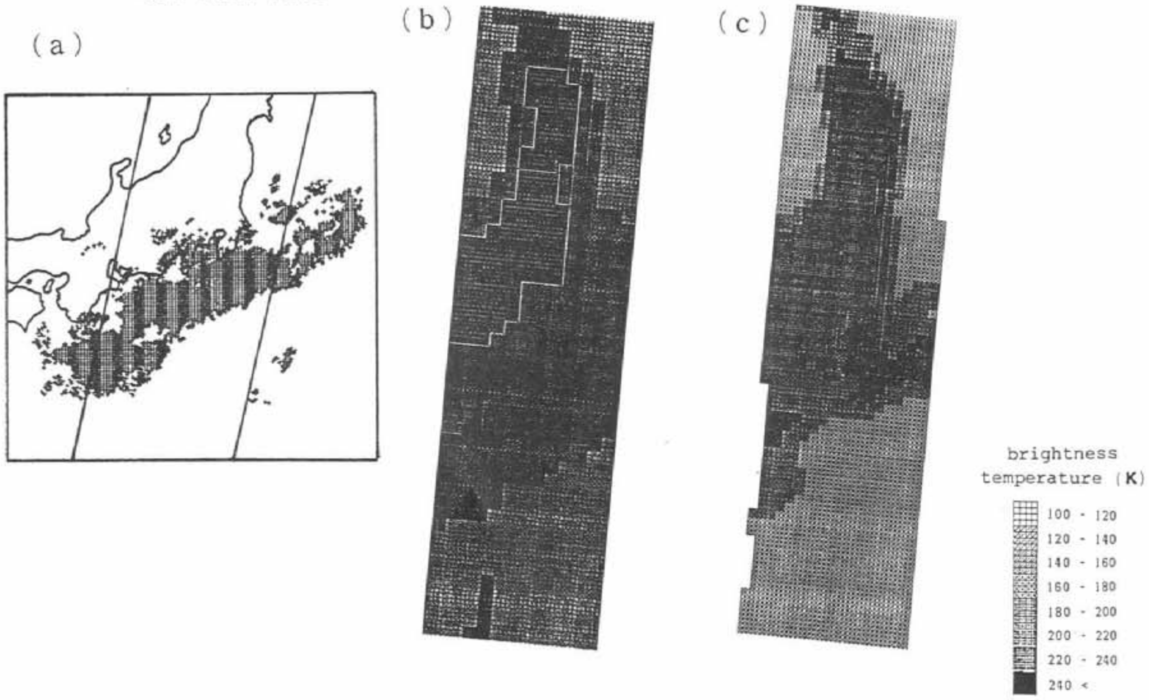

Figure 2. Comparison of radar rain rate map (a) and MSR brightness temperature maps at 23.8 GHz (b) and 31.4GHz (c) taken on 20 July 1987.

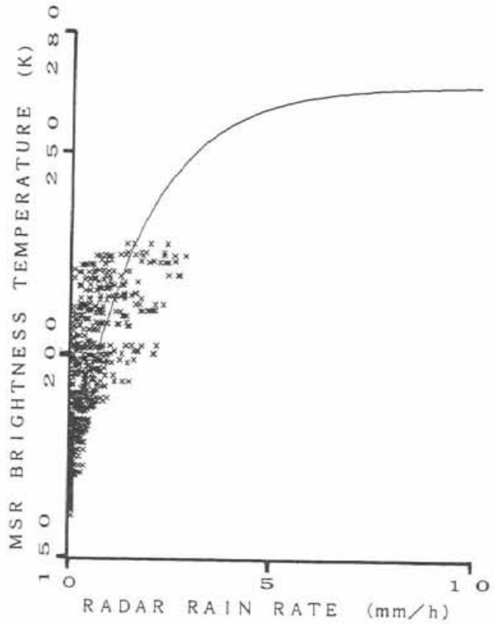

Figure 3. Brightness temperature at 31.4GHz as a function of rain rate (MSR vs Mt. Fuji radar). The solid line is the approximate curve.

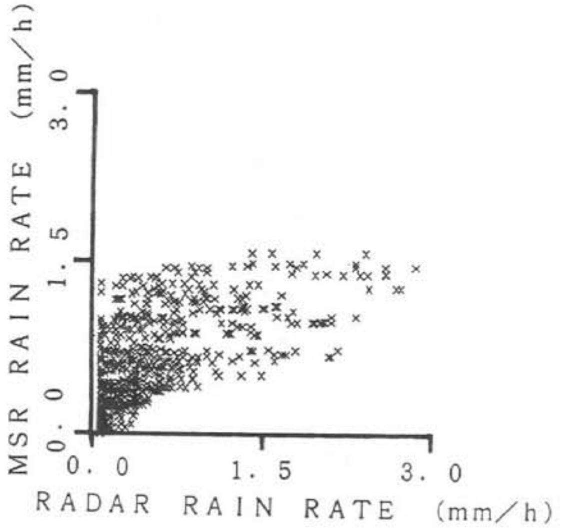

Figure 4.

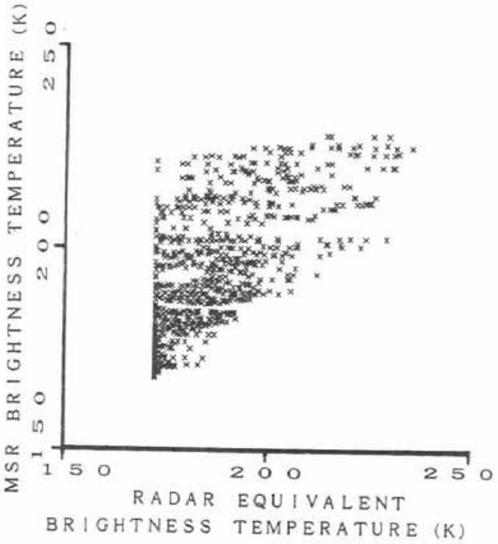

Figure 5.

Figure 4. Scatter diagram of radar and MSR-derived rain rates.

Figure 5. Scatter diagram of radar and MSR-derived brightness temperature.