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A TRMM Rain Radar Algorithm - Bright Band Detection and Rain Type Classification

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1. INTRODUCTION

A rain radar is installed on board the TRMM (Tropical Rainfall Measuring Mission) satellite, which is to be launched by a Japanese H-II rocket in FY 1997 [1]. A TRMM rain radar algorithm for detecting bright band and classifying rain types has been developed. Tests of the algorithm have been made by using airborne rain radar data [2] and by using synthetic data based on Tao's storm model [3].

This paper outlines the above TRMM rain radar algorithm and shows some results of bright band detection and rain type classification.

2. OUTLINE OF THE ALGORITHM

Figure 1 shows the flow of the algorithm. Detection of bright band is carried out first. Then rain is classified into three types based on whether the bright band exists or not. Finally, detection of the "warm rain" is made. Details are as follows:

Detection of Bright Band

The bright band detection is made by searching a peak of measured reflectivity factor Zm along the radar beam above the Earth's surface. This peak search uses a spatial filter method. The spatial filter is given as follows:

$$\begin{pmatrix} -1 & -1 & -1 \\ 2 & 2 & 2 \\ -1 & -1 & -1 \end{pmatrix} \qquad (1)$$

where the vertical direction corresponds to the range, and the horizontal direction corresponds to the antenna scan angle. This spatial filter is based on the following 2nd derivative of Zm with respect to the range:

$$d^2Zm/dr^2 \sim - \{ -Zm(r-\Delta r) + 2 \cdot Zm(r) - Zm(r+\Delta r) \} \qquad (2)$$

When the output of the above filter exceeds a predetermined value, it is basically judged that the bright band exists. (Determination of bright band requires some additional conditions to be satisfied.)

Classification of Rain Types

Rain is classified into three types, that is, (1) stratiform rain, (2) convective rain, and (3) other type of rain, in the following way:

(1) **Stratiform rain:** When the bright band (BB) exists and Zm in the rain region is smaller, i.e. Zm <= 35 dBZ (tentative value), it is classified as stratiform rain.
(2) Convective rain: When BB exists and Zm > 35 dBZ in the rain region or when BB does not exist but Zm above the Earth's surface is large, i.e. Zm > 30 dBZ (tentative value), it is classified as convective rain.
(3) Other type of rain: When BB does not exists and Zm above the Earth's surface is small, i.e. Zm <= 30 dBZ (tentative value), it is classified as the other type of rain.

Detection of "Warm Rain"

In the case of convective rain, a further classification is made to determine whether it is "warm rain" or not. When the following condition is satisfied, it is classified as "warm rain".

$$H\_storm < H\_freeze - (margin) \quad (3)$$

where H_storm is the height of the storm top of convective rain and H_freeze is the height of freezing level, which can be estimated from the NMC (National Meteorological Agency) or JMA (Japanese Meteorological Agency) forecast data given 4 times a day or from a climatological surface temperature data. In (3), a margin is introduced in order to make sure that the algorithm detects "warm rain". We have decided to use the climatological surface temperature data for the estimation of H_freeze because of the following reason.

Figure 2 shows an example of scatter plot of H_freeze estimated from NMC forecast data versus climatological surface temperature. Figure 2 (a) shows the data in the latitude region between 35°S and 35°N and Figure 2 (b) shows those between 22.5°S and 22.5°N. The straight lines in the figure show H_freeze estimated from the climatological surface temperature data assuming a lapse rate of the temperature as 5°C/km. The figure indicates that the climatological surface temperature data can be used for the estimation of H_freeze especially in the latitude region between 22.5°S and 22.5°N, where the existence of "warm rain" is highly expected.

3. RESULTS

Figure 3 shows an example of test data generated from a 10 GHz airborne data [2]. The abscissa shows the range and the ordinate shows the antenna scan angle θ from -17° to +17° with $\theta = 0°$ as the nadir direction. A band of strong Zm which appears about 4/5 from the top of the figure is the echo from the sea surface. The bright band appears about 5 km above the sea surface echo.

Figure 3 also shows the result of bright band detection and the result of rain type classification. When the bright band exists, it is classified as stratiform rain or convective rain according to the rule (1) explained in the previous section. When the bright band does not exist, it is classified as convective rain or other type of rain according to the rules (2) and (3) in the previous section. However, the "warm rain" does not exist in this example.

Acknowledgement

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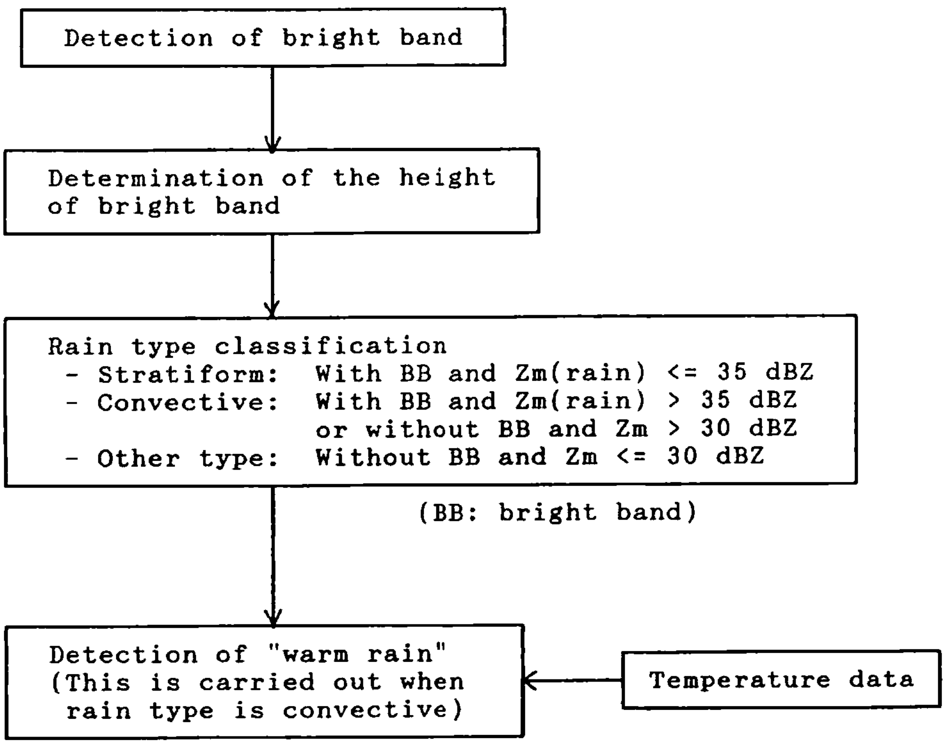

Figure 1 Flow diagram of the TRMM rain radar algorithm for detecting bright band and classifying rain types

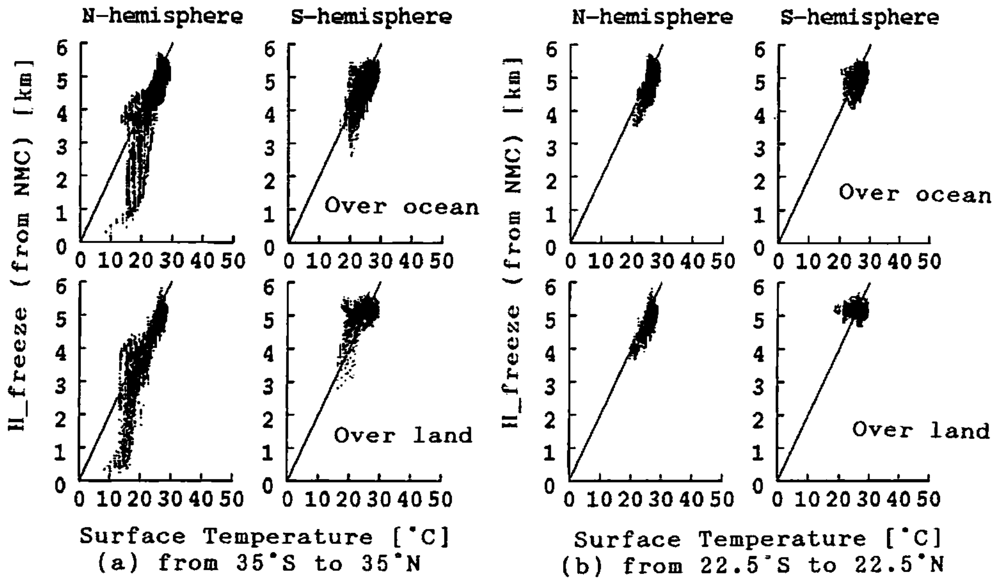

Figure 2 Freezing height (from NMC) vs. climatological surface temperature for two different latitude regions. NMC data are those from 00Z in Feb. 1, 1995 to 18Z in Feb. 2, 1995.

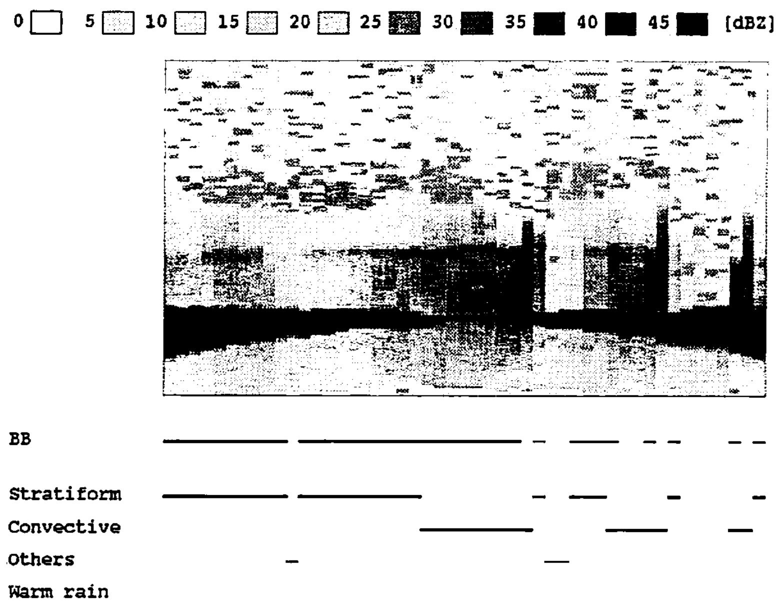

Figure 3 Example of simulation data for the TRMM rain radar originated from a 10 GHz airborne data, and the result of bright band detection and rain type classification.