ON RAIN TYPE CLASSIFICATION ALGORITHM TRMM PR 2A23 V6

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1. INTRODUCTION

Detection of bright band (BB) and rain type classification are made in the TRMM precipitation radar (PR) algorithm 2A23. The purpose of this presentation is to explain major changes in 2A23 V6 (version 6), which is the most recent version, and to discuss issues on a possible improvement of the algorithm, which might be necessary for the future GPM (Global Precipitation Measurement) precipitation radar.

2. MAIN CHANGES IN 2A23 V6

Main changes in 2A23 V6 are as follows:

(a) Rain type is expressed by 3-digits number (but by 2-digits number in V5).

(b) All the shallow isolated are classified as convective in V6, while in V5 most of the shallow isolated are stratiform.

(c) In addition to the above shallow isolated, shallow non-isolated is newly detected in 2A23 V6. Types of shallow non-isolated can be stratiform, convective, or other depending on its echo strength.

(d) Changed a convective threshold in horizontal pattern method from 40 dBZ to 39 dBZ; the effect of this change on the convective count, however, is very small.

(e) Changed the criteria for other type, which makes a substantial decrease in the number of other type of rain. When rain is 'certain' and rain type is 'other', it most probably indicates that there exists ice cloud only.

(f) When BB is detected, rain type is stratiform. (In the previous versions, however, rain type can be convective even though BB is detected in a very exceptional case.)

(g) Upper and lower boundaries of BB, and the width of BB are added to the output.

(h) Over-sample data are used in the detection of BB, and over-sample range bin numbers are used for computing heights.

(i) Rain probable is introduced. (Internal use in 2A23 only, and the type of rain probable is other.)

3. OUTLINE OF 2A23 V6

Figure 1 shows a flow chart of 2A23, where rain type classification is made by two methods: one is a vertical profile method (V-method) [1] and the other a horizontal pattern method (H-method), the latter of which is basically based on the University of Washington convective/stratiform separation method [2]. Both methods classify precipitation into three categories: stratiform, convective, and other. These different results by the two methods are unified, and 2A23 outputs the unified rain type, which also has three main categories: stratiform, convective, and other.

3.1. V-method

In the V-method, detection of bright band (BB), rain type classification, and detection of shallow isolated and shallow non-isolated are made.

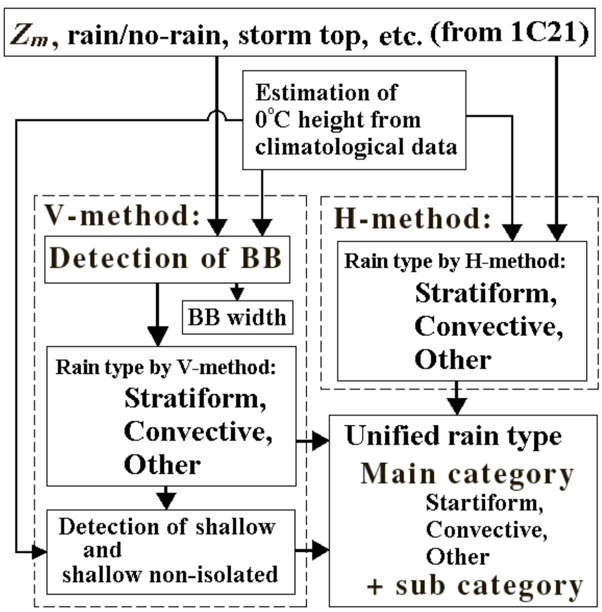

Fig. 1 Flow chart of 2A23 (V6)

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3.1.1. Detection of BB

Detection of BB is carried out with several steps: the idea is to detect clear BB peaks first in one scan of data consisting of 49 angle bins of data, and when clear BB peaks are detected, then goes on to detect less clear BB peaks.

Detection of a clear BB peak is carried out (i) by a peak detection using a spatial filter [1] and (ii) by examining the slope of measured reflectivity factor Z in the upper part of BB peak, the latter approach is added in 2A23 V6.

When BB is detected, the width of BB is then determined. The width of BB in the nadir direction is defined as the difference between the upper boundary of BB and the lower boundary of BB, where the definition of the lower boundary of BB is very close to that by Fabry and Zawadzki [3], and the definition of the upper boundary is the one which is somewhere in between the definition by Fabry and Zawadzki [3] and that by Klaassen [4]. In directions other than nadir, the effect of smeared BB peak is empirically corrected for.

3.1.2. Rain Type by the V-method

When BB is detected, the precipitation is classified as stratiform. Then the V-method goes on to the detection of convective precipitation, which is characterized by a strong radar echo. When the precipitation type is neither stratiform nor convective, it is classified as other type. The threshold for convective rain by the V-method is 39 dBZ.

3.1.3. Shallow Isolated and Shallow Non-Isolated

When the height of storm top, H_storm, is much lower than the estimated height of freezing level, H_freeze, it is defined as shallow rain. Here, H_freeze is estimated from a climatological surface temperature at sea level, Ts, by the following equation:

$$\mathrm{H\_freeze} \;=\; (\mathrm{Ts} - 273.13)/6.0 \qquad (1)$$

where the lapse rate of temperature is assumed to be 6.0°/km.

There are two levels of confidence for the shallow rain; 'possible' and 'certain'.

Over ocean, H_freeze−H_storm>1.0 [km] means shallow rain 'possible', and H_freeze−H_storm>1.5 [km] means shallow rain 'certain'. Over land, however, the judgment is always shallow rain 'possible'.

When the region of shallow rain is isolated from the other non-shallow, rain certain areas, this shallow rain is called as shallow isolated. Shallow non-isolated is defined as the shallow rain which is not shallow isolated.

3.2. H-method

The H-method is based on the University of Washington convective/stratiform separation method [2], which examines the horizontal pattern of Z, having a 2-km horizontal resolution, at a given height.

The following modifications are needed because the horizontal resolution of the TRMM PR is about 4.3 km, and because examining the horizontal pattern of Z at a given height would become impossible over high mountain areas.

(a) Instead of examining a horizontal pattern of Z at a given height, a horizontal pattern of Zmax(in R) is examined; here, Zmax(in R) is the maximum of Z along the range for each antenna scan angle in the rain region.

(b) Parameters are changed so that they may be suitable for the TRMM data with a 4.3 km horizontal resolution. Choice of parameters was made before the launch of TRMM using a test ground validation (GV) data in such a way that a 4.3 km resolution data produces almost the same result as that with a 2 km resolution GV data.

(c) Other type, a third category, of rain is introduced to handle noise.

In the H-method, detection of convective rain is made first. If one of the following condition is satisfied at a pixel, which correspond to the angle bin data being considered, it is judged that the pixel is a convective center:

(1) Zmax(in R) exceeds 39 dBZ, or
(2) Zmax(in R) stands out against the background area.

Rain type for a convective center is convective, and rain type for the (four) pixels nearest to the convective center is also convective.

If rain type is not convective and if the radar echo is certain to exist in the rain region, rain type is stratiform.

Rain type by the H-method is other if the radar echo below H_freeze (plus 1 km margin) at a given angle bin is very weak so that the echo in the rain region may possibly be noise. This means that the other type by the H-method consists of (i) cloud only case and (ii) noise only case.

3.3. Unified Rain Type

Rain types by the two different methods are unified, and the unified rain type is expressed by 3-digits number, whose first digit indicates the main category of the type; 1: stratiform, 2: convective, and 3: other.

Let the rain type for the i-th angle bin be rainType[i]. Then the main category of the unified rain type is obtained by

$$(\mathrm{Unified\ rain\ type}) \;=\; \mathrm{rainType[i]}/100. \qquad (2)$$

Table 1 shows the unified rain type and, in the parentheses, the type by the V-method and that by the H-method.

Table 1 Unified rain type

The last column shows population [%] of each type in the V6 data of Feb. 1998.

Type (V,H)	comments	[%]
Stratiform		**80.7**
100 (S,S)	BB detected.	29.6
110 (S,O)	BB detected.	0.0
120 (O,S)	BB not detected but may exist.	28.0
130 (S,C)	BB detected.	2.6
140 (O,S)	BB hardly expected.	5.6
152 (O,S)	Shallow non-isolated detected.	8.2
160 (O,S)	Rain hardly expected near surface. BB may exist but not detected.	4.1
170 (O,S)	Rain hardly expected near surface. BB hardly expected. Maybe cloud.	2.4
Convective		**16.8**
200 (C,C)		1.7
210 (O,C)		7.8
220 (C,O)		0.0
230	This number is not used in V6.	
240 (C,S)		0.1
251 (C,C)	Shallow isolated detected.	0.0
252 (C,C)	Shallow non-isolated detected.	0.0
261 (C,O)	Shallow isolated detected.	0.0
262 (C,O)	Shallow non-isolated detected.	0.0
271 (O,C)	Shallow isolated detected.	0.3
272 (O,C)	Shallow non-isolated detected.	0.9
281 (C,S)	Shallow isolated detected.	0.0
282 (C,S)	Shallow non-isolated detected.	0.0
291 (O,S)	Shallow isolated detected.	5.9
Other		**2.5**
300 (O,O)		2.4
312 (O,O)	Shallow non-isolated detected.	0.0
313 (O,O)	If sidelobe clutter were not rejected, the type would be 271 or 291.	0.1

In the parentheses (V,H), rain type by V-method and that by H-method are shown with the following abbreviations; S: Stratiform, C: Convective, and O: Other.

Table 1 also shows the population of each rain type obtained for the V6 data in February 1998.

In 2A23 V6, all the shallow isolated is classified as convective because shallow isolated has convective characteristics [5], though the radar echo of shallow isolated is usually weak.

Shallow non-isolated, however, can be stratiform, convective, or other. Most of the shallow non-isolated is classified as stratiform because its radar echo is usually weak.

4. STATISTICAL RESULTS

Figure 2 shows angle bin dependence of the count of BB, detected in February 1998. The angle bin number 25 in the abscissa corresponds to the nadir direction, and the off nadir angle at the scan edge is about $\pm 17°$.

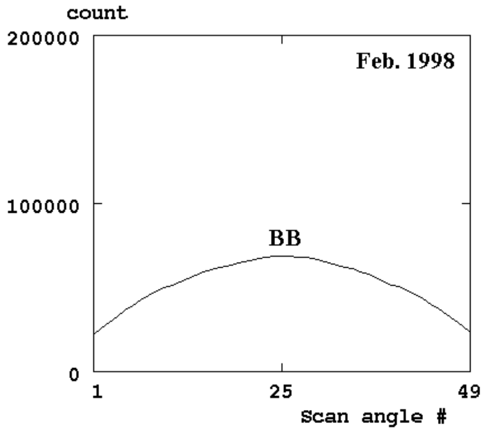

Fig. 2 BB count (2A23 V6)

scan #25: nadir direction

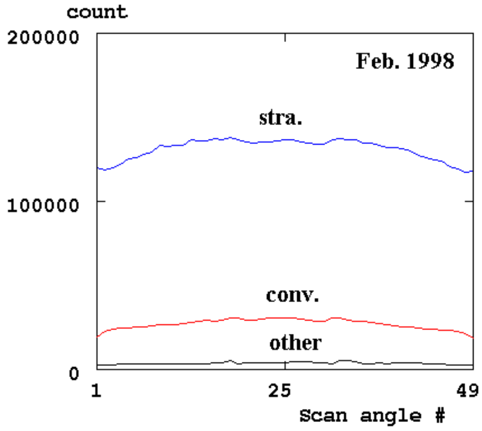

Fig. 3 Rain type count (2A23 V6)

scan #25: nadir direction

Figure 2 shows a sharp decrease of BB count near scan edges. This occurs because the effect of smearing in the shape of BB becomes larger near scan edges, and it becomes very difficult to detect the smeared BB.

Figure 3 shows angle bin dependence of the count of each of the three main categories of unified rain type. The figure indicates that the most populous type is stratiform, and the least is other. The count of other type in 2A23 V6 becomes very small when compared with that in version 5 (not shown), because of changes in the parameters for characterizing ‘other’. In version 6, ‘other’ means ice cloud only or possibly just noise.

In Figure 3, the count of stratiform rain is rather flat but the count decreases near scan edges. This occurs because the stratiform rain includes an appreciable number of shallow non-isolated (see Table 1). When the storm top is low, the rain echo may be masked by a smeared surface clutter near scan edges and not detected; where the smearing of surface echo occurs due to the same mechanism as the smearing of the BB peak profile.

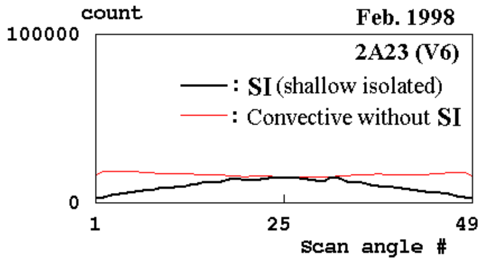

Fig. 4 A detail of convective count

Figure 3 shows that the count of convective rain also exhibits a dependency on the angle bin. If the majority of convective rain has a tall storm top and a strong precipitation rate, we would expect that the convective count may be almost independent of the angle bin, because the high storm top is free from the clutter by smeared surface. In 2A23 V6, however, all the shallow isolated is classified as convective, and the shallow isolated occupies a large part of convective rain (see Table 1).

Figure 4 separately shows the angle bin dependence of the count of shallow isolated (thick line) and that dependence of the count of convective rain which excludes the count of shallow isolated (thin line). The count of shallow isolated shows angle bin dependence because of the masking effect by the surface clutter. The convective count which excludes the count of shallow isolated is almost independent of the angle bin, which is a characteristics of tall and strong precipitation.

5. FUTURE PLANS

Though the algorithm 2A23 V6 works fine, further improvement is needed such as on the following items:

- Detection of BB.
- Estimation of H_freeze.
- Rain type classification,
  - including parameter tuning.

At least two kinds of improvement are needed in the detection of BB: one is to solve the problem of missing clear BB in some rare cases, and the other is to decrease the chance of falsely detecting BB, which actually is not BB. These problems may remain in the TRMM PR data analysis, but a substantial improvement is expected in the future Global Precipitation Measurement (GPM) project, because a dual frequency radar is planned to be used in GPM [6].

In 2A23 V6 (and in the previous versions), the height of freezing level, H_freeze, is estimated from a climatological surface temperature. A possible use of NECP reanalysis data [7] for estimating H_freeze will be studied in 2A23 V7. A possible use of analysis data by JMA or NECP will also be studied for a near-real time processing of GPM data.

Dependence of rain type on classification parameters will be studied and the result will be assessed by visually inspecting the vertical profile of Z. This study would be very time consuming.

Improvement of main-lobe clutter rejection is closely related to the improvement of rain type classification because, if the main-lobe clutter rejection fails, a strong surface clutter would wrongly be identified as a strong rain echo, or vice versa. Generation of a digital elevation map by using the TRMM PR data is now under way [8]. A possible replacement of currently used digital elevation map with a more accurate one [9] which is corrected by the TRMM PR derived elevation map will be studied.

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