THE OBSERVATION-BASED IMPROVEMENT OF THE PRH ALGORITHM TO ESTIMATE LATENT HEATING

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1. INTRODUCTION

The estimation of the global distribution of latent heating (LH) is one of the important goals of the TRMM project. Recently, several algorithms to retrieve LH from TRMM data have been developed. Among them, the "precipitation radar heating" (PRH) algorithm (Satoh and Noda, 2001; Satoh 2004) applies TRMM/PR data to the thermodynamic retrieval algorithm using ground-based radar data, based on the method of Roux and Sun (1990). This PRH algorithm enables to estimate LH both over the ocean and the land in equal quality.

However, the PRH algorithm needs some parameters which are not observed directly by TRMM/PR; vertical air motion, cloud top height, etc. Because these parameters are also essential to the estimation of LH in the PRH algorithm, the assumptions of these parameters in the PRH algorithm have to be examined their validity, by comparing each parameters to the result of the observation, and testing variation of these parameters in the calculation of PRH algorithm. In this study, we try to improve PRH algorithm by applying the observational results on these implicit parameters.

2. OUTLINE OF THE PRH ALGORITHM

The PRH algorithm is an application of the thermodynamic retrieval technique (Roux and Sun, 1990) by limiting dimensions only for vertical. The estimated LH by the PRH algorithm is principally dominated by the vertical gradient of the precipitating water respect to the motion of the precipitating particles $w + Vt$, where w is the vertical air motion and Vt is the fall speed of the precipitating particles. If the precipitating water increases respect to the direction of the motion of the precipitating particles, the increase of the precipitating water is regarded as the result of the condensation and sublimation. In contrast, decrease of the precipitating water is regarded as the result of the evaporation of the precipitating particles. Thus, the vertical distribution of the precipitating water and vertical air motion is substantially important factor.

Though the vertical air motion cannot be obtained directly by TRMM/PR, the PRH algorithm assumes the vertical profile of the vertical air motion as the fourth-order polynomial function. The heights of the w=0 "node" are decided from the type of the precipitation (convective / stratiform / anvil / shallow) and the vertical profile of precipitating water. The amplitude of the function is iteratively estimated to match the vertically-integrated LH to the surface rainfall. For more detailed description, see Satoh (2004).

These algorithm descriptions indicate that the estimation of the vertical air motion is the key factor in the PRH algorithm. Especially, the heights with w=0, or "node" of the fourth-order function, is the important factor because (1) the "node" determines the direction of the vertical air motion in each layer and (2) the determined "node" heights are basically not adjusted in the iterative procedure.

In the following sections, we examined the setting of the two special "node", cloud top height and bright-band height, using the observational data.

3. CLOUD TOP HEIGHT

In the original PRH algorithm by Satoh (2004), the cloud top height, equal to the ceiling of the updraft, is determined by adding constant value to the echo top height. The constants are determined for each type of the convection; 0.5 km for "convective" and "shallow" rays, while 1.0 km for "stratiform" and "anvil" rays.

We tried to examine more realistic relationship between cloud top height and echo top height from the observational data. The observational cloud top height is obtained from the TRMM/VIRS, the infrared radiometer. We regarded the brightness temperature in the 12 μm window channel in TRMM/VIRS as the cloud-top temperature.

Figure 1 shows the results of the comparison

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between the cloud top height and TRMM/PR echo top height. In the figure, highest number appeared around the thick line. The line is approximately expressed as the first-order equation of

$$Zct\ [\text{km}] = Zet\ [\text{km}] * 3/8 + 10 \quad (1)$$

where *Zct* and *Zet* are the heights of the cloud top and the echo top, respectively. On the other hand, another (secondary) axis can be also found around the line where *Zct* = *Zet* below 10-km in the echo top height. The former relationship (Eq. 1) is found in the statistics in all type of the convection, while the latter *Zct*=*Zet* relationship is significant in “convective” and not found in “anvil”. From these results, we adopted Eq. 1 for “stratiform” and “anvil” rays. For “convective” and “shallow” rays, in contrast, we adopted the relationship *Zct* = *Zet* + 0.5, same as original Satoh (2004) version. We regard the relationship of Eq. 1 expressed overcastting clouds for “convective” and “shallow” rays.

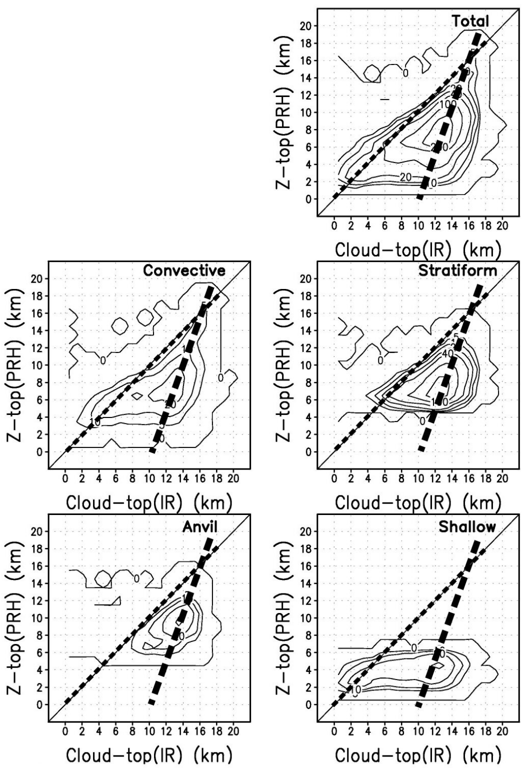

Fig. 1: Contoured frequency diagrams between TRMM/PR echo top height (ordinate) and TRMM/VIRS cloud top height (abscissa), for all (right upper), convective (left middle), stratiform (right middle), anvil (left lower), and shallow (right lower). The data is from selected 13 scenes around EAR (80E-120E, 15S-15N), including land, coastal and oceanic region. See text for the solid and dashed lines.

4. W=0 HEIGHT AROUND MELTING LEVEL

In the PRH algorithm, the vertical air motion is set to zero at the tropopause height, cloud top height, surface height and bright-band height (Zbb). The Zbb is only adopted for “stratiform” ray, and the setting is critical to the estimation of LH, because the height divide the rain-water-rich layer into the layer with the upward motion aloft and the downward motion beneath. In the original PRH algorithm, the Zbb is set to the height of the bright band, where the air temperature is estimated as +3 degree -C.

The vertical motion within the precipitating system is examined using the Equatorial Atmosphere Radar (EAR) at Sumatra Island (EQ, 100E), which can measure the vertical air motion within the precipitating system directly, by Mori et al. (2004). The results indicated that the averaged vertical air motion shows significant gap at about 5.5-km height between upward motion aloft and downward motion beneath. This height is 0.5 to 1 km higher than the radiosonde-observed 0 degree-C height. The past studies using VAD or dual-Doppler analyses (e.g. Houze, 1989; Biggerstaff and Houze, 1991) also showed the similar results.

Based on these results, we modified the height of zero vertical air motion as 1-km higher than the original version, in which the height of zero vertical motion is at bright band height.

5. CASE STUDY

The PRH algorithm with the above two modification is applied to a precipitating event in western Pacific ITCZ, which analyzed in Katsumata and Yoneyama (2004).

The two panels in Fig. 2 show the result with the original PRH algorithm by Satoh (2004), and the modified algorithm for the present study. The domain-averaged LH for these two calculations are also shown in Fig. 3. The large differences between two results are (1) the altitude of the border between negative and positive value around the melting level, and (2) altitude of largest positive value. Both altitudes are higher in the new algorithm than in the original. This could be one of the possible solutions for the previously-known difference of PRH result from other LH algorithm, in which the positive LH value appeared in the lower altitude than other calculations. However, the positive LH value is also peaky in the new algorithm around 7-km height, and the thickness of the positive LH layer is not extended significantly to the upper altitude.

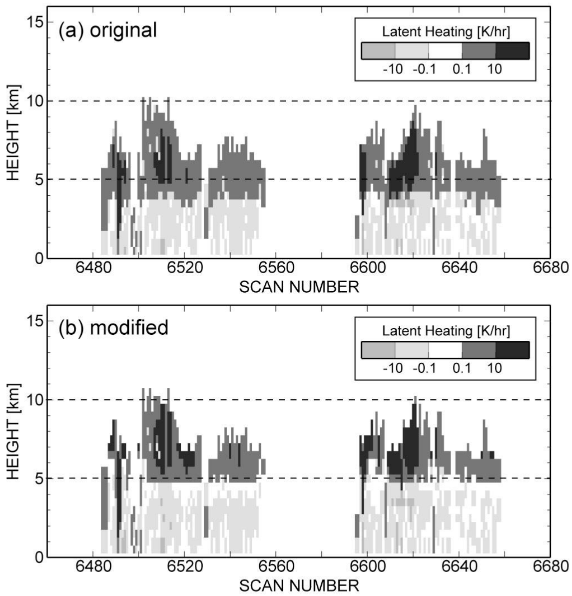

Fig. 2: Vertical cross sections of the distribution of the estimated latent heating by (a) original and (b) modified PRH algorithm, for the ITCZ MCSs in 21 Jun. 2000, around (7N, 140E). (Corresponding to MCS2 and MCS3 in Katsumata and Yoneyama (2004)) The nadir rays of TRMM/PR data are adopted.

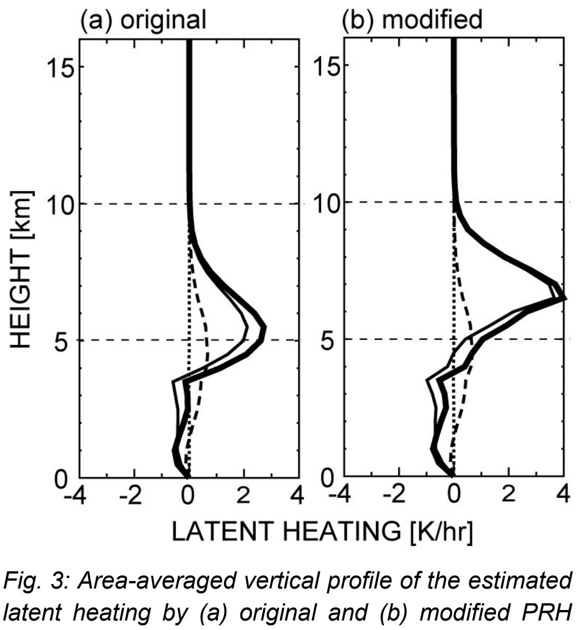

Fig. 3: Area-averaged vertical profile of the estimated latent heating by (a) original and (b) modified PRH algorithm from all (solid thick), convective (dashed), stratiform (solid thin) and anvil (dotted) rays, for the same case of Fig. 2.

6. SUMMARY

The PRH algorithm is examined and modified on the two parameters related to the vertical air motion; cloud top height and w=0 height around the 0 degree-C height. The observation-based modification results the upward shift of the whole of the positive LH layer and also the peak altitude of positive LH value. The modified result is more similar to that in the previous studies (e.g. Houze, 1982) than the original PRH, while the profile becomes peakier. The further examinations for other cases and temporal / spatial average will be carried out for the further discussion and improvement.

< ACKNOWLEDGMENT >

The TRMM/PR and TRMM/VIRS data are provided by NASA and JAXA. The study is partly supported by JAXA, as a part of the TRMM 4th research announcement.

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