Uncertainty Analysis of Rain/no-rain Classification Method Using Polarization Corrected Temperature at 89 GHz (PCT89) from Satellite-based Microwave Sensor

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1. Introduction

- Passive microwave sensors are sensitive to vertical distributions of hydrometeors, and are used for quantitative measurements of precipitation and understanding the characteristics of precipitation system.
- For precipitation measurement using the passive microwave sensor, rain/no-rain classification (RNC) is implemented preferentially by a number of algorithms.
- In particular, PCT89 derived from observed microwave brightness temperatures (TBs) is used as a simple indicator for RNC which can estimate scattering signals free from the influence of surface with a high resolution.
- Uncertainties associated with the threshold of PCT89, however, exist due to the heterogeneous distributions of microphysical properties depending on the various forms of precipitating clouds.
- The purpose of this paper is to investigate the uncertainty of the PCT89 RNC method quantitatively.

2. Data and Methodology

I. Description of Satellite Data

PCT Equation:

$$\text{PCT} = (\beta TB_h - TB_v)/(\beta\text{-}1)$$

where β was given by 0.45 for SSM/I 85.5 GHz (Spencer et al. 1989).

PCT at 89 GHz of GPM GMI (PCT89)

The cut-off threshold of 255 K was used for the rain rates about 3.0 mm/h (Fig. 1).

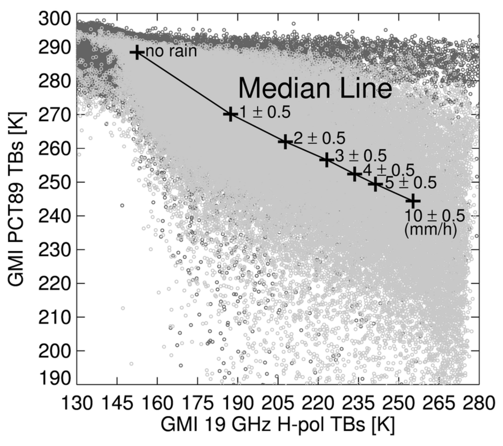

Fig. 1. Scatterplot of the GMI PCT89 and the horizontally polarized 19 GHz TBs. The black circle is the pixel classified as no-rain, while the gray circle means the rain pixel. The cross on the median line also indicates the DPR rain rates.

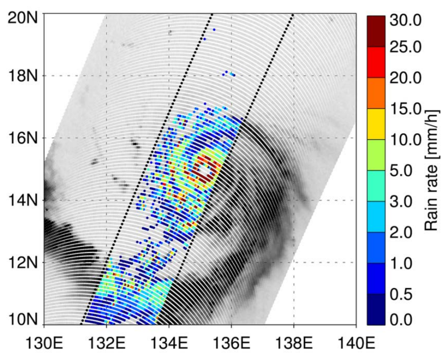

Fig. 2. GPM GMI 89 GHz FOV averaged DPR rain rate with PCT89 background.

Target Region & Period

The 45 scenes of precipitation observed in the Western Pacific Ocean from 2014 to 2016

II. Classification of Cloud Type

Classification Algorithm

GPM DPR L2 "cloud type classification" algorithm (Awaka et al. 2016)

V-method & H-method

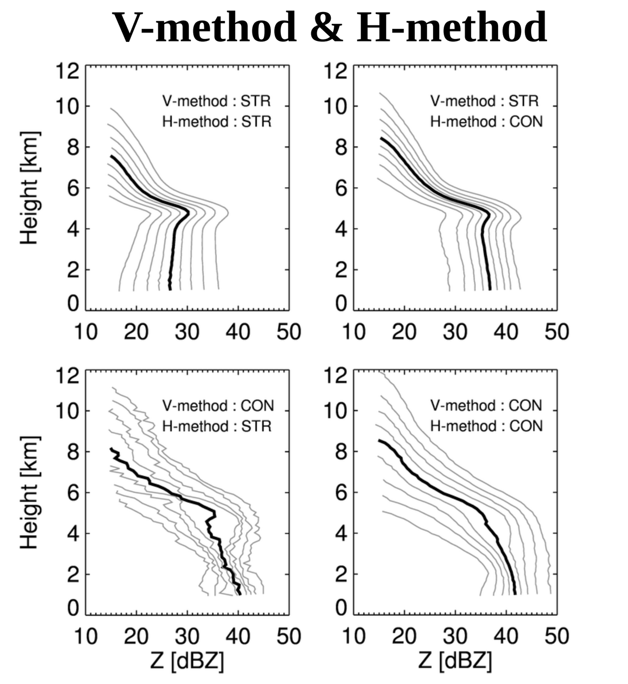

Fig. 3. GPM DPR reflectivity profile. The bold line means the median, and each thin gray line means a 10 % quantile from 10 % to 90 % (Funk et al. 2013).

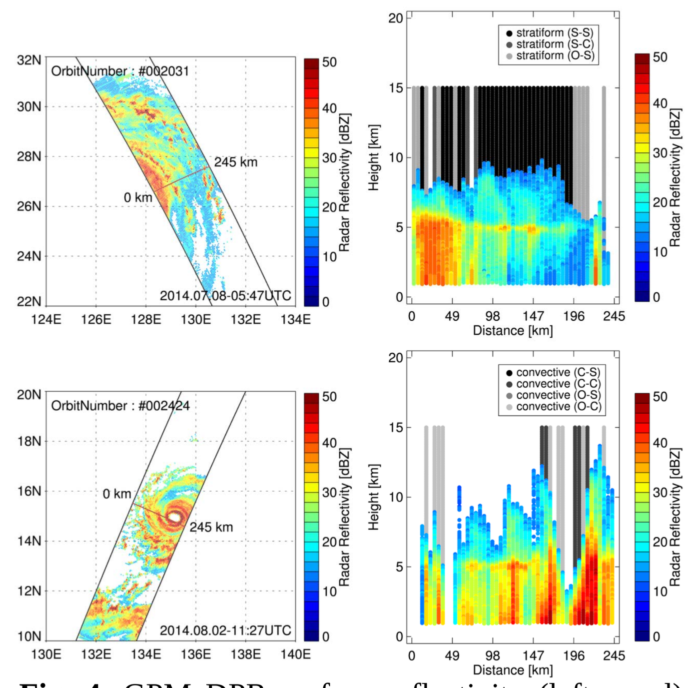

Fig. 4. GPM DPR surface reflectivity (left panel) and vertical cross section of reflectivity (right panel) with cloud type information.

Categorized Type (eleven species)

	V	H	BB	Shallow	Small	Anvil
Stratiform(S-S)	STR	STR	BB			
Stratiform(S-C)	STR	CON	BB			
Stratiform(O-S)	OTH	STR				
Convective(C-S)	CON	STR				
Convective(C-C)	CON	CON				
Convective(O-S)	OTH	STR				
Convective(O-C)	OTH	CON				
Shallow Isolated	-	-		Isolate		
Shallow Non-isolated	-	-		Non-isolated		
Small Size Cell	-	-			Small	
Anvil (noise/cloud)	-	-				Anvil

3. Results and Discussion

I. PCT89 Distributions under Rain/no-rain Conditions

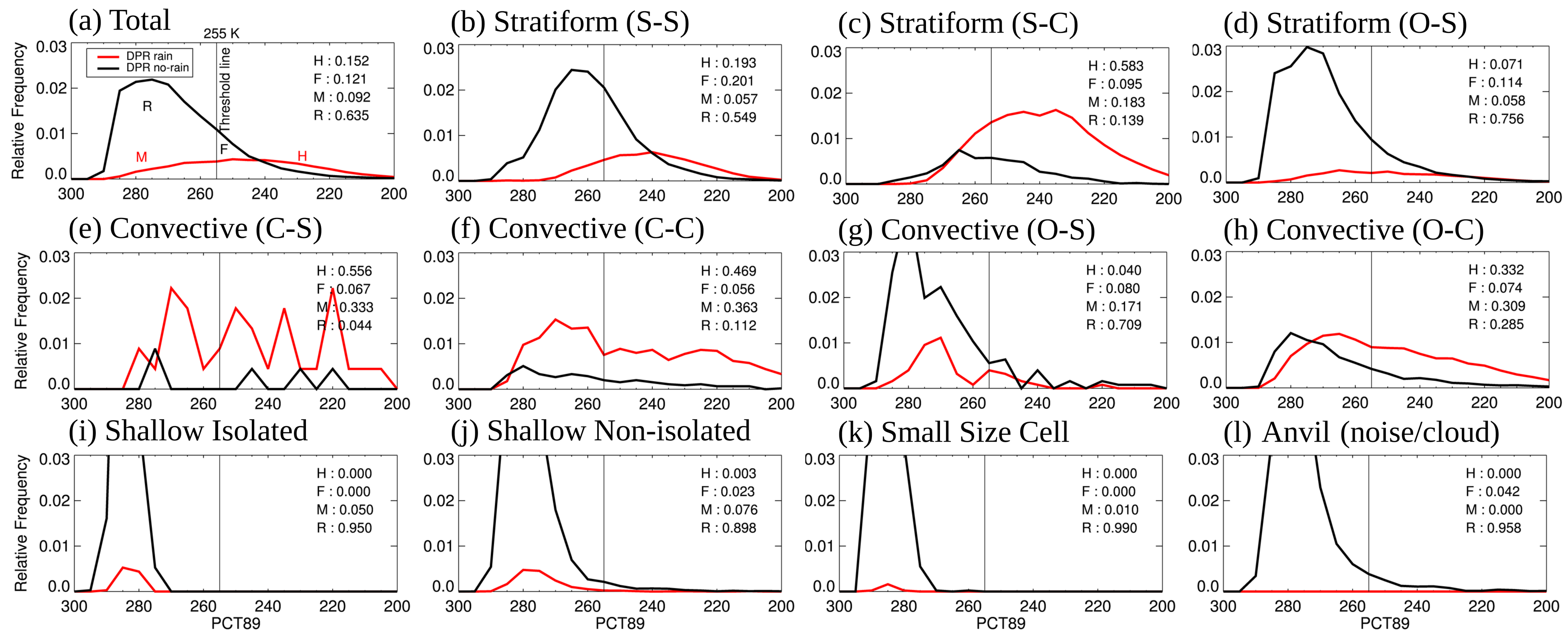

Fig. 5. Relative frequency for PCT89 under rain/no-rain conditions. The red line represents the PCT89 distribution of rain clouds, while the black line represents no-rain clouds. H, F, M, and R indicate fractions of hit, false alarm, miss, and correct rejection, respectively. Left top (a) is total cloud type. Figure (b) to (l) indicate the eleven species of the cloud types in order.

- The PCT89 distributions under **the DPR rain (signal)** and **the no-rain (noise)** overlap each other, so they cannot be completely divided by the cut-off threshold of 255 K.

II. Median Profiles of Reflectivity

$$Category = \begin{cases} 1, & if\ 265\,K \le PCT89 < 285\,K \\ 2, & if\ 245\,K \le PCT89 < 265\,K \\ 3, & if\ 225\,K \le PCT89 < 245\,K \end{cases}$$

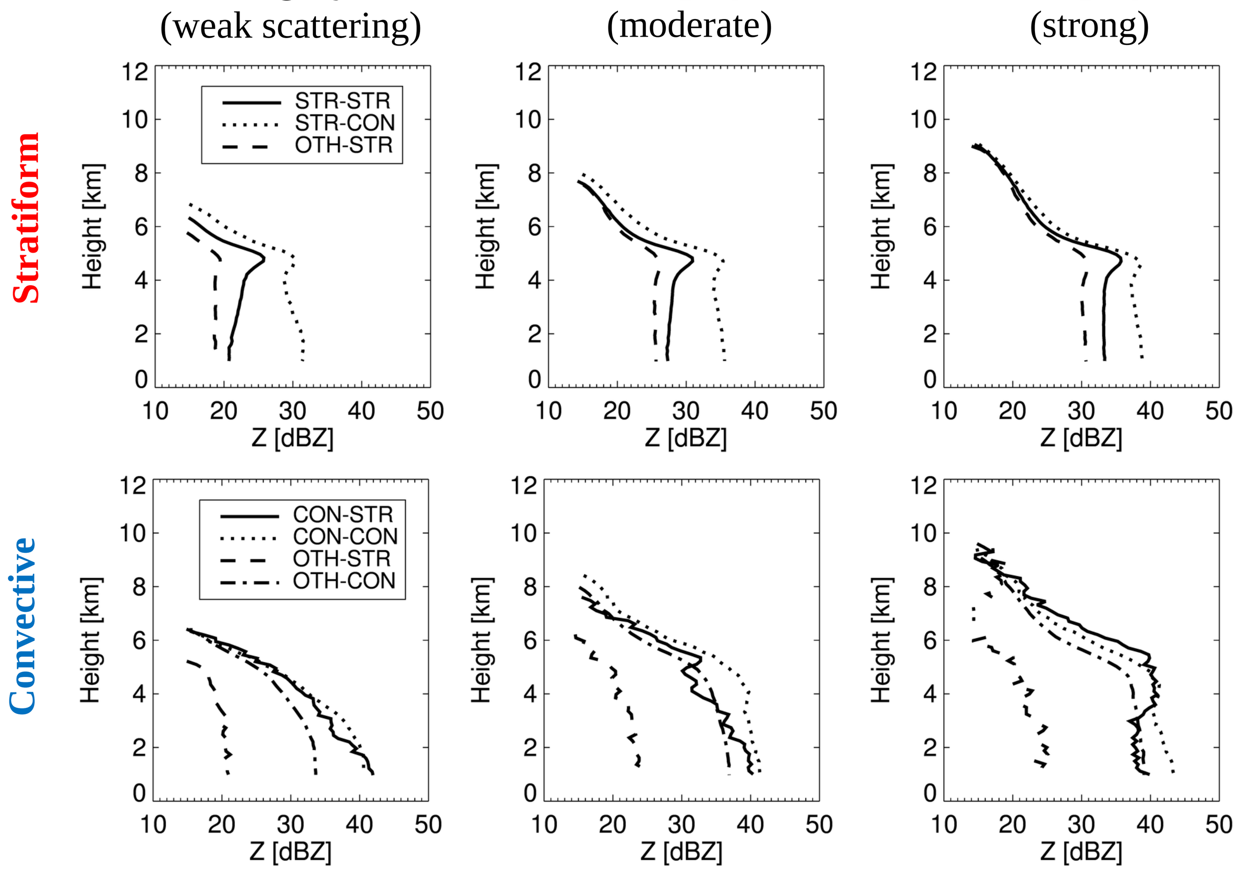

Fig. 6. GPM DPR median reflectivity profiles for each cloud type. Upper panels: stratiform types. Lower panels: convective types.

- Increasing radar reflectivity toward the surface indicates that a collision-coalescence process is actively progressing, and then the size of the rainfall particles increase.
- On the contrary, the decreasing or constant radar reflectivity of the lower layers means that the rainfall particles are placed in an environment where they are susceptible to evaporation.

II. Median Profiles of Reflectivity (Continued)

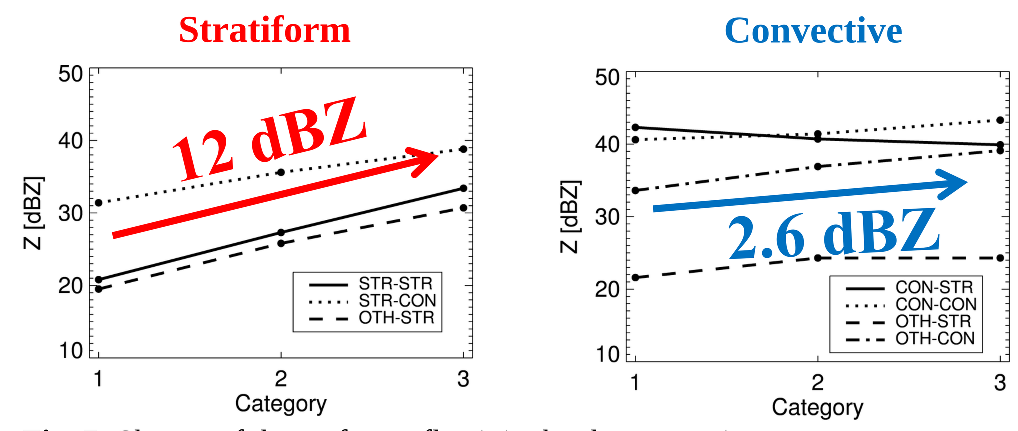

Fig. 7. Change of the surface reflectivity by the categories.

- As the scattering increases from category 1 to 3, the surface reflectivity for **stratiform (S-S) type** increases by 12 dBZ. This means that **the increase in the scattering by ice particles in the upper layers is related to the increase in the collision-coalescence process in the lower layers.**
- However, the surface reflectivity for **convective (O-C) type** increases by only 2.6 dBZ, and even there is a type that the surface reflectivity tends to decrease. This indicates that **the collision-coalescence process in the lower layers is not proportional to the increase of the scattering in these types.**

III. Skill Score (Roebber Diagram)

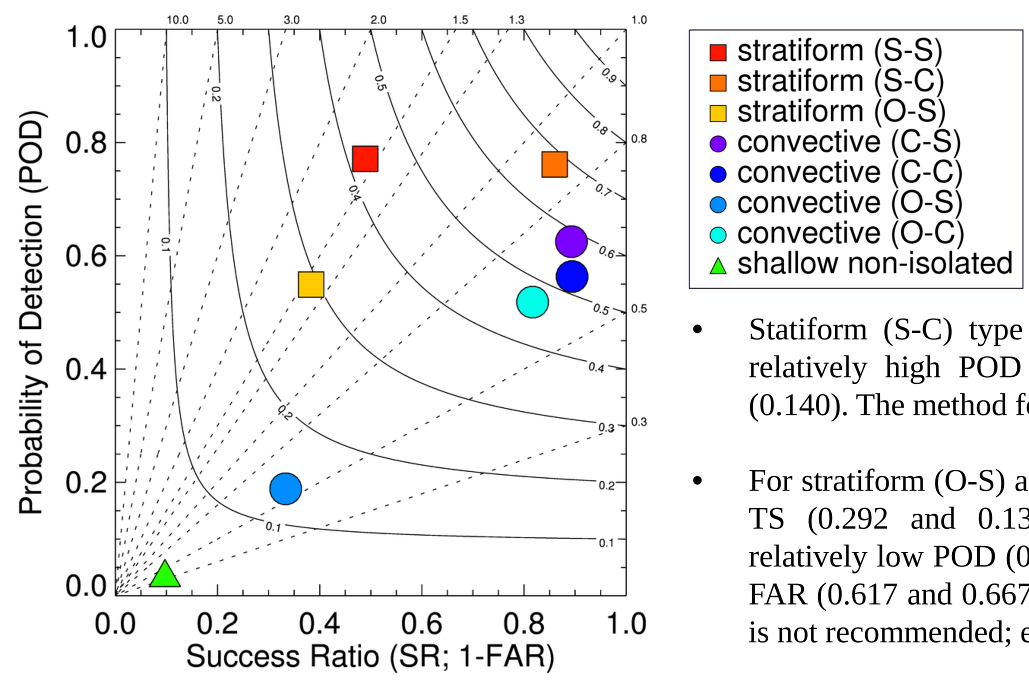

Fig. 8. Skill score of PCT89 RNC method for each cloud type shown as Roebber diagram (Roebber 2009).

- Statiform (S-C) type has the highest TS (0.677) with the relatively high POD (0.761) and the relatively low FAR (0.140). The method for this case is quite appropriate.
- For stratiform (O-S) and convective (O-S) type, the values of TS (0.292 and 0.137) are exceptionally poor with the relatively low POD (0.549 and 0.189) and the relatively high FAR (0.617 and 0.667). In these cases, the use of the method is not recommended; especially for convective (O-S) type.

Skill Score

	# rain	# no-rain	POD	FAR	BIAS	TS
Stratiform (S-S)	5,979	17,961	0.771	0.511	1.576	0.427
Stratiform (S-C)	2,605	794	0.761	0.140	0.885	0.677
Stratiform (O-S)	3,864	25,976	0.549	0.617	1.433	0.292
Convective (C-S)	40	5	0.625	0.107	0.700	0.581
Convective (C-C)	749	151	0.563	0.106	0.630	0.528
Convective (O-S)	53	198	0.189	0.667	0.566	0.137
Convective (O-C)	5,335	2,989	0.518	0.183	0.634	0.464
Shallow non-isolated	532	6,233	0.032	0.903	0.329	0.025

4. Concluding Remarks

- An uncertainty analysis of the PCT89 RNC method for various precipitating cloud types were conducted.
- The adequacy of the threshold can be assessed differently for each cloud type.
- The reflectivity profiles represented precipitation systems.
- The PCT89 RNC method was difficult to apply universally to all types because there was a huge TS difference (0.54) between them, even if the other types such as shallow, small size cell, and anvil cloud showing weak relationships between scattering signals and surface rain rates excluded from analysis,
- Further study about the physical structure of each precipitating cloud might lead to a better understanding of this uncertainty analysis.

5. References

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