On the hail detection using satellite passive microwave radiometers and precipitation radar

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Data

- The station hail reports in China during 1998-2013 are compiled based on two qualified datasets from the China Meteorological Administration (CMA), including hail occurrence time.
- Hail reports in U. S. are from the *Storm Data* of the National Climatic Data Center (NCDC).
- The TRMM Precipitation Feature (PF) database (Liu et al., 2008) is utilized to collocate the hail reports and study hail PFs properties. First two-year GPM observations are also used.

Definition of hail PFs

- The PFs possibly associated with hail are searched within one degree and one hour from the PF's centroid location and observation time.
- One hail report to one PF relationship. 1) if multiple PFs are found within one degree and one hour of a hail report, the PF with the coldest minimum 37 GHz PCT is selected as the hail PF. 2) when one PF is collocated with multiple hail reports, the hail report with the largest hail diameter and the nearest distance from the PF centroid.
- Definition of non-hail PFs. 1) in US, PFs not collocated with hail reports, 2) in China, PFs within 1° from stations not collocated with hail reports.
- 2000 m topography is used to distinguish high elevation and low elevation hail reports and PFs in this study.

Table 1. Collocated hail numbers and all hail reports in different hail size intervals in China and US south of 36° N.

D (mm)	China				U.S.			
	High elevation (≥2000 m)		Low elevation (<2000m)		High elevation (≥2000 m)		Low elevation (<2000m)	
	All	Collocated	All	Collocated	All	Collocated	All	Collocated
<5	4318	445	199	17	0	0	0	0
5-9	1409	180	362	40	0	0	10	2
10-29	189	17	154	12	532	39	45123	4677
30-49	15	3	23	1	202	6	13668	1472
50-79	0	0	6	0	51	0	2917	38
>=80	0	0	0	0	6	0	333	41

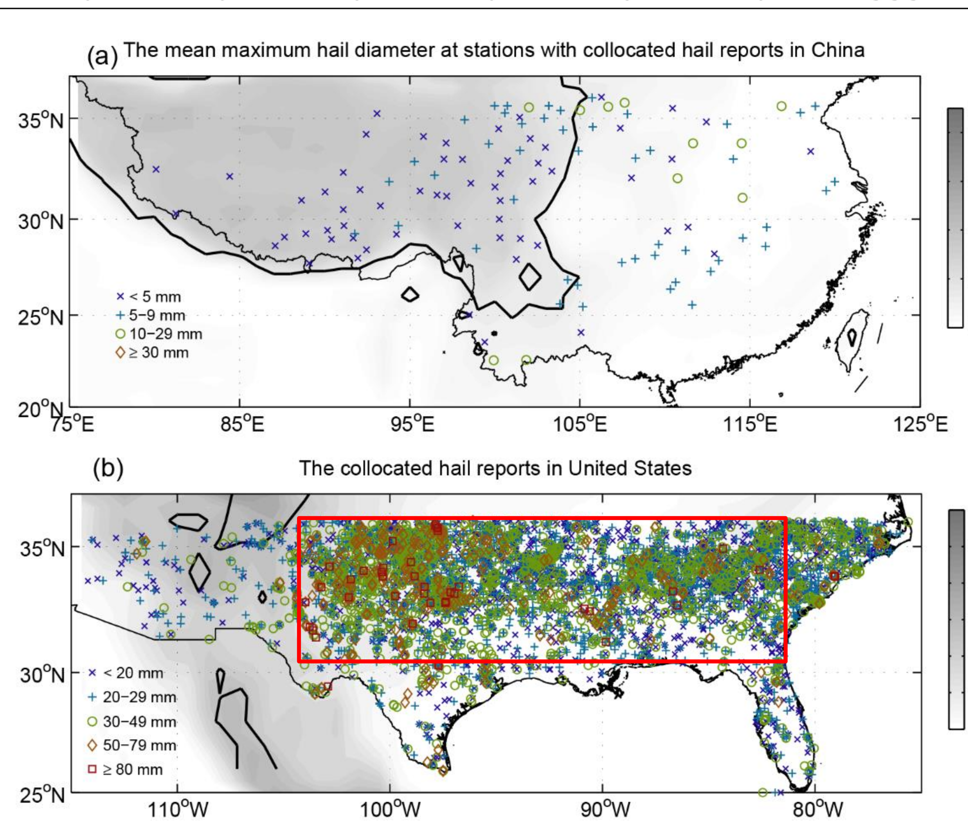


Fig. 1. (a) Locations of hail reports collocated with TRMM Precipitation Features in (a) China and (b) US.

Reflectivity profiles of hail PFs

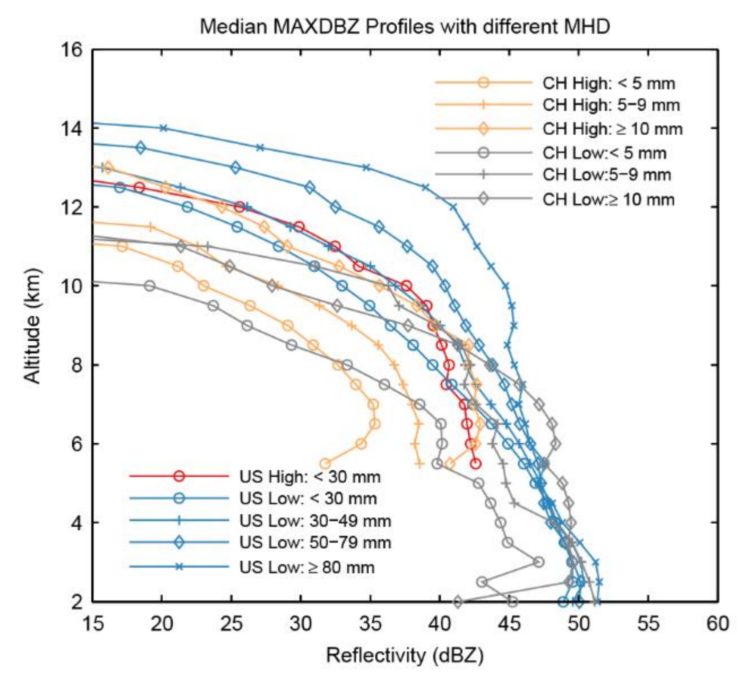


Fig. 2. Median maximum reflectivity profiles of hail Precipitation Features with different maximum hail diameter (MHD).

The larger the hail size, the stronger the maximum reflectivity and reflectivity above 6km are. High-Elev PFs have weaker maximum reflectivity.

Hail detection Criteria

Following the discussions of hail PF characteristics in China and U.S., we examine the possibility of using radar reflectivity and passive microwave brightness temperature in the detection of large hail and its application to construct global proxy hail climatology. To optimize the detection criteria, forecast skill scores are utilized.

Forecast skill scores

Meet Threshold		Collocated Hail PF (RES)	
		Yes	No
No-hail PF (RPF)	Yes	a (Hits, N(RES) ≤S)	b (False, N(RPF) ≤S)
	No	c (Misses, N(RES)>S)	d (Correct, (RPF)>S)

Reflectivity VS echo top T | MIN37PCT VS MIN85PCT

$$FAR = \frac{b}{a+b}$$

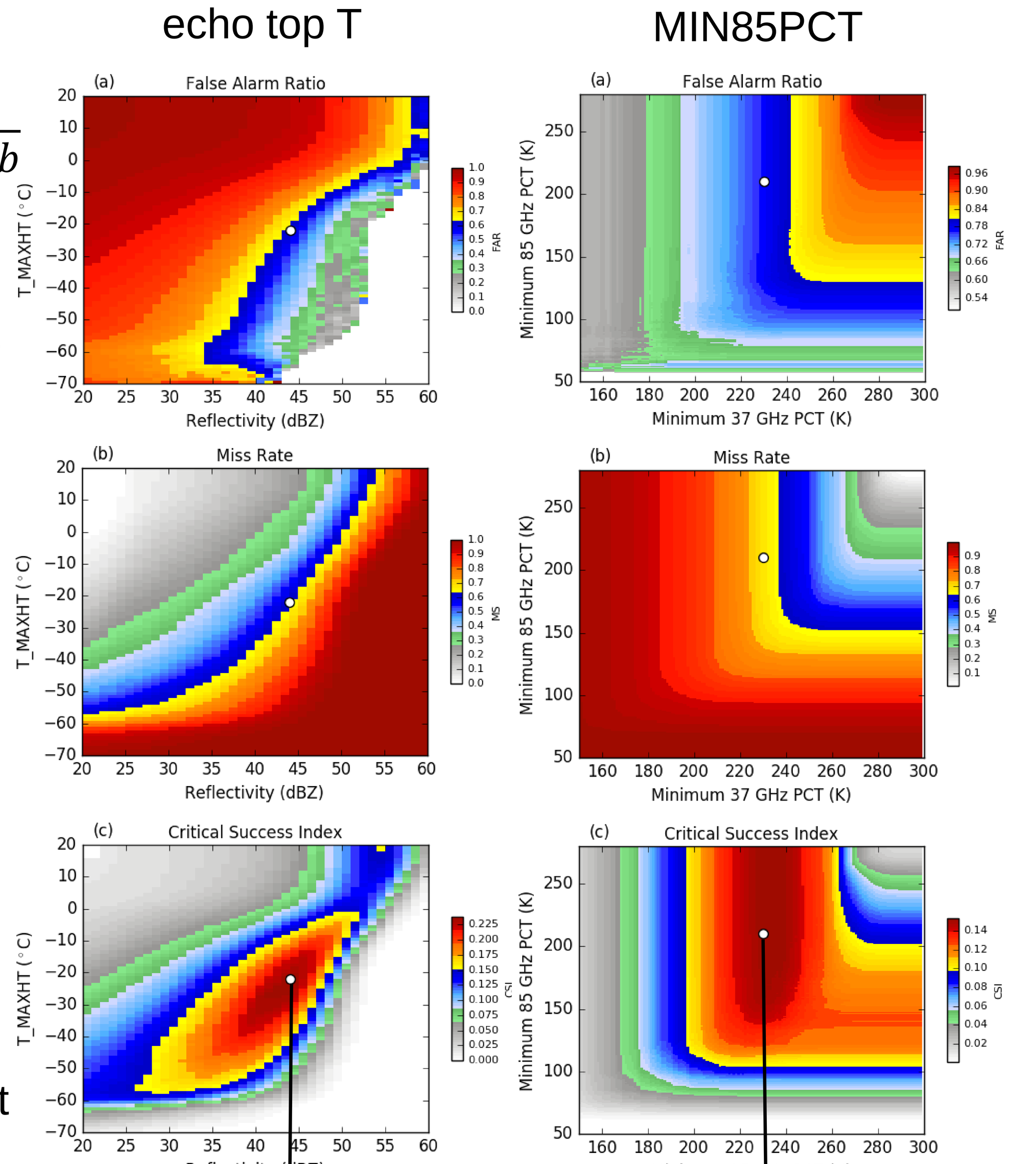
0 is perfect

$$MS = \frac{c}{a+c}$$

0 is perfect

$$CSI = \frac{a}{a+b+c}$$

1 is perfect



Global hail map

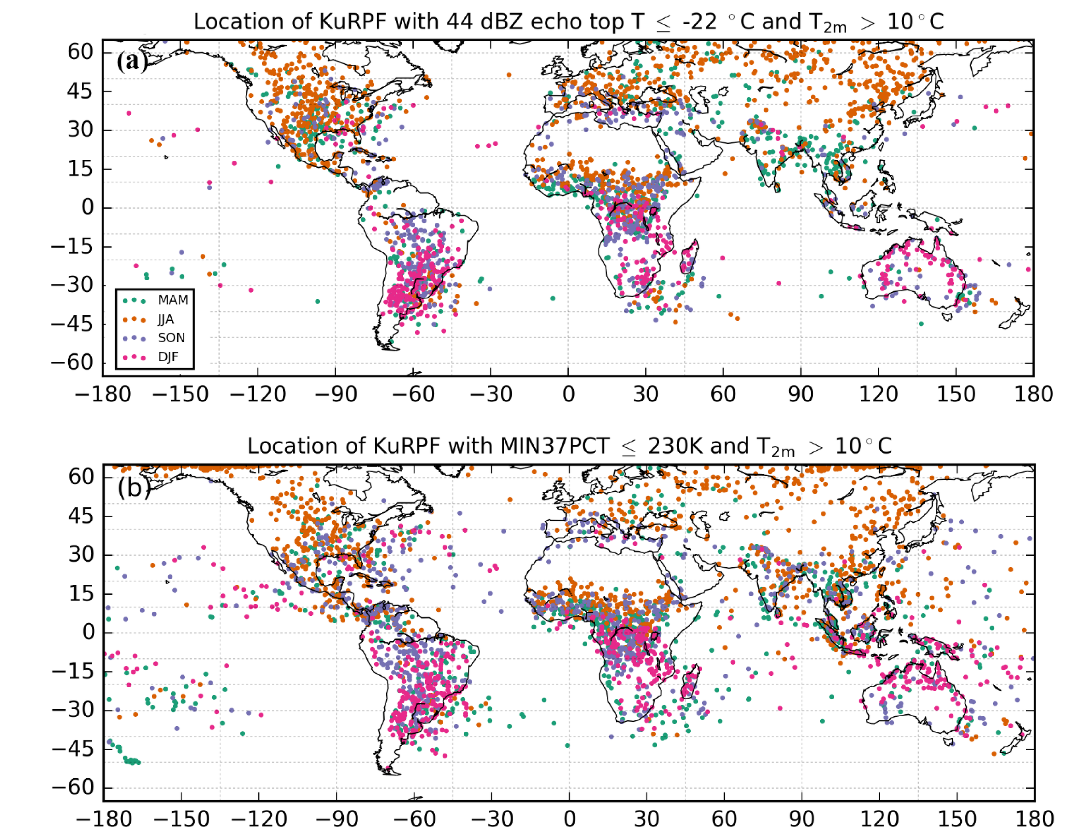


Fig. 4. Locations of GPM PFs with (a) $T_{44\ dBZ\ echo\ top}$ less than –22°C and (b) minimum 37 GHz less than 230 K. The PFs are defined using observations of GPM Core Observatory from April 2014 to March 2016,

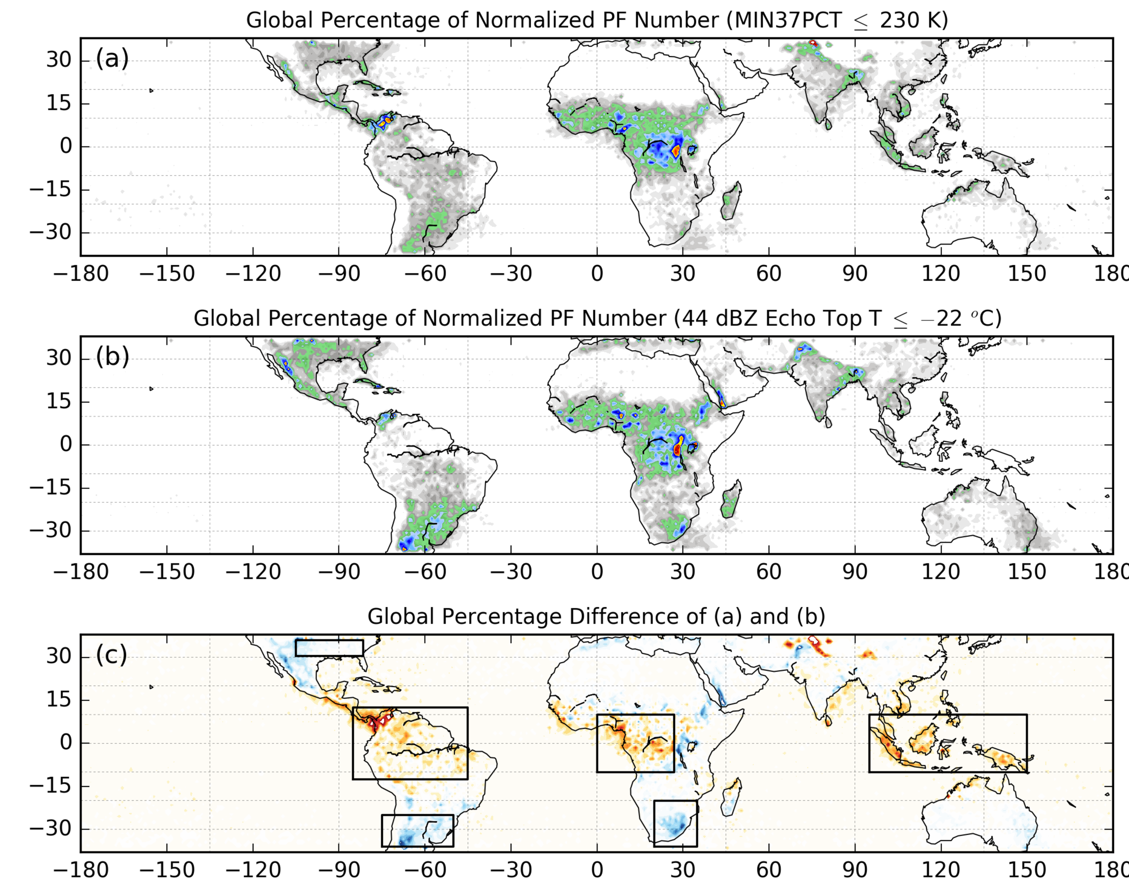


Fig. 5. Global percentage distribution of normalized number of PF from 1998 to 2013 with (a) minimum 37 GHz less than 230 K; (b) $T_{44\ dBZ\ echo\ top}$ less than –22°C; (c) percentage difference between (a) and (b). Note the overestimation in tropics by PCT method.

dBZ vs. PCT methods

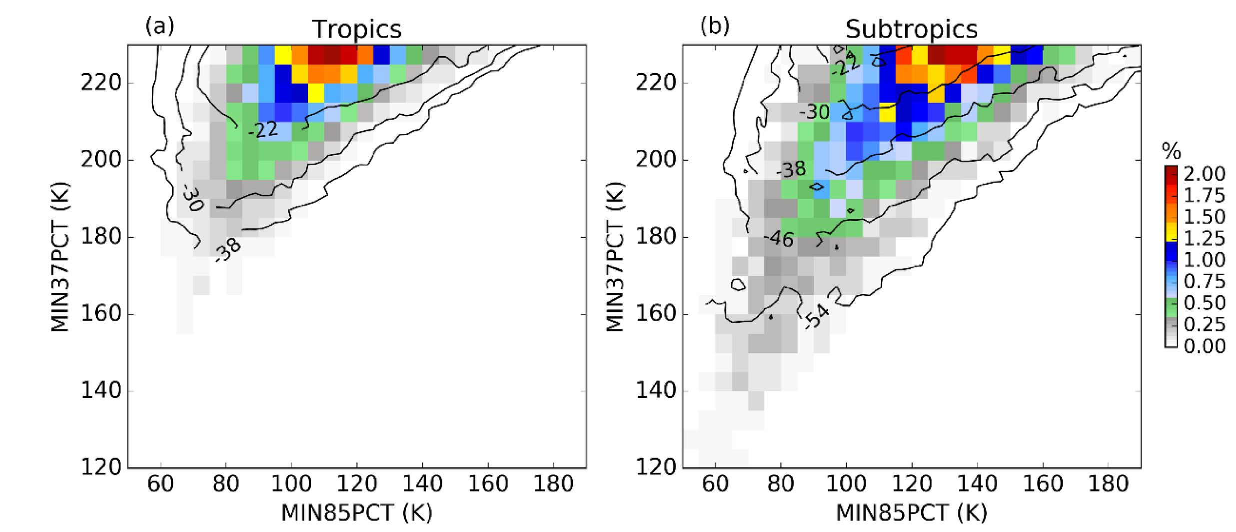


Fig. 6 2D histograms of land PFs categorized by minimum 85 and 37 GHz PCT over (a) three tropical regions (the Maritime Continent, Central Africa and Amazon) and (b) three subtropical regions (SE US., South Africa, and Argentina). The mean values of PF $T_{44\ dBZ\ echo\ top}$ are overlapped with contours. Most of subtropical PFs with 37 PCT < 230K have $T_{44dBZ\ echo\ top}$ colder than -22°C.

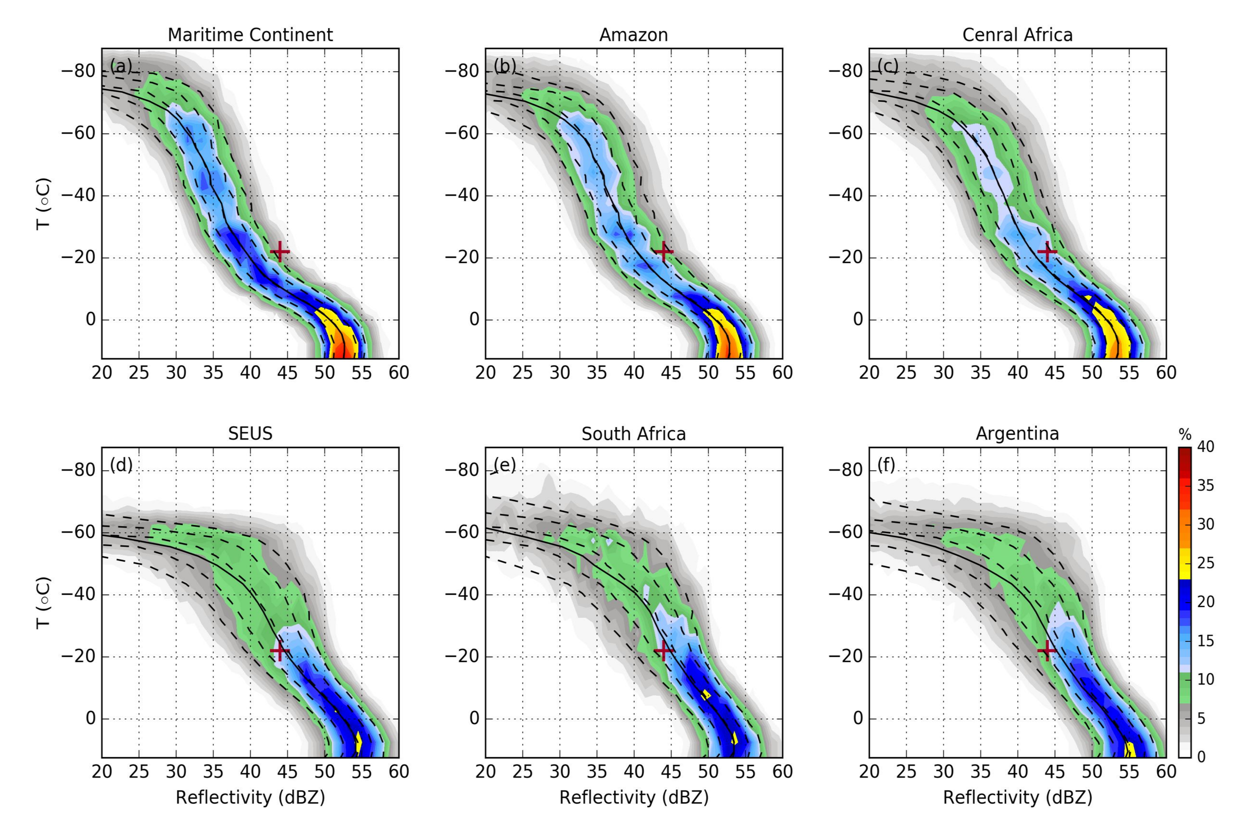


Fig. 7 CFADS of maximum reflectivity profiles in land PFs with minimum 37 GHz PCT < 230 K over different regions. The plus marker is the point with $T_{44\ dBZ\ echo\ top}$ at –22°C. The dashed lines are reflectivity at 10th, 25th, 50th, 75th, and 90th percentiles and the solid lines are the mean reflectivity at each temperature level. Note that a large portion of tropical samples with cold 37 GHz PCT have weaker reflectivity values that does not satisfy dBZ method.

Summary

- The maximum reflectivity profiles of hail PFs show stronger reflectivity as the hail size increases, especially at levels above 6 km for storms with larger hail sizes, which are consistent in both China and U.S.
- Two criteria ($T_{44\ dBZ\ echo\ top}$ < –22° C and 37 GHz PCT < 230 K) may be used to distinguish hail. Applications of these criteria present reasonable global distributions of large hail with discrepancies over specific regions.
- The low PCT PFs in tropics have higher echo top and weaker reflectivity in middle levels. On the contrary, in the subtropics, the low PCT PFs have stronger reflectivity between –10°C and –30°C.

Reference

Ni, X., C. Liu, Q. Zhang and D. Cecil, 2016., JGR-Atmos.
Ni, X., C. Liu, D. Cecil, and Q. Zhang. JAMC (In preparation)