Overlap of Extreme Convective Intensities and Extreme Rain Rates from TRMM and WSR-88D Perspectives

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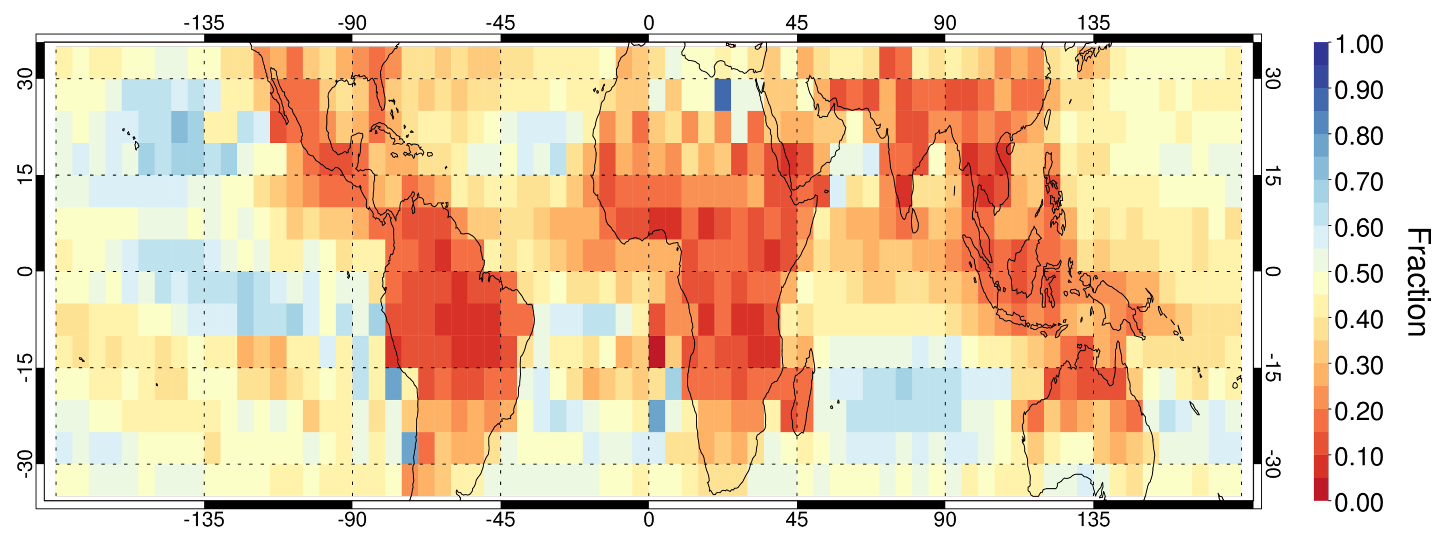
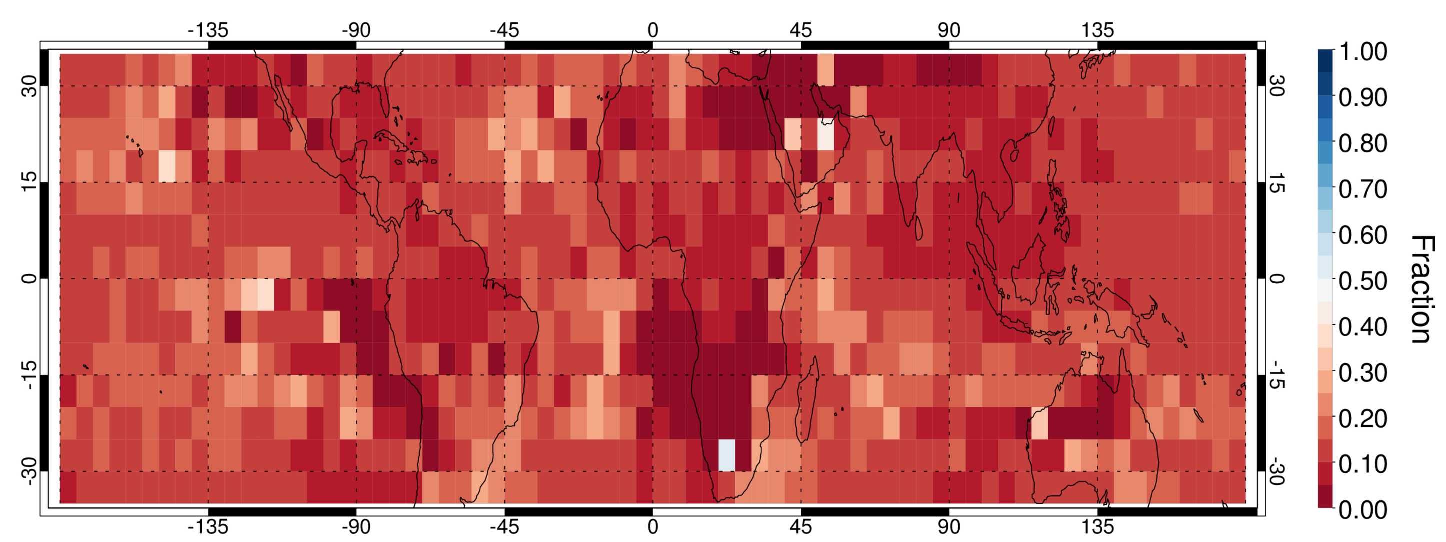
1. MOTIVATION



Hamada et al. (2015) found that the overlap between systems with the most extreme rain rates and those with the most extreme convective intensities using the maximum 40 dBZ echo height as a proxy was low, notably over land regions. This finding is reproduced in the map above. However, this finding relies on TRMM 2A25 V7 retrievals of attenuation-corrected Ku-band reflectivity and variable reflectivity-rain rate (Z-R) retrievals. This research evaluates the validity of the Hamada et al. (2015) conclusion by making comparisons of TRMM retrievals with WSR-88D retrievals over the Southeastern United States (SEUS) with potential implications for global satellite retrievals of extreme rain rates.

2. METHODOLOGY

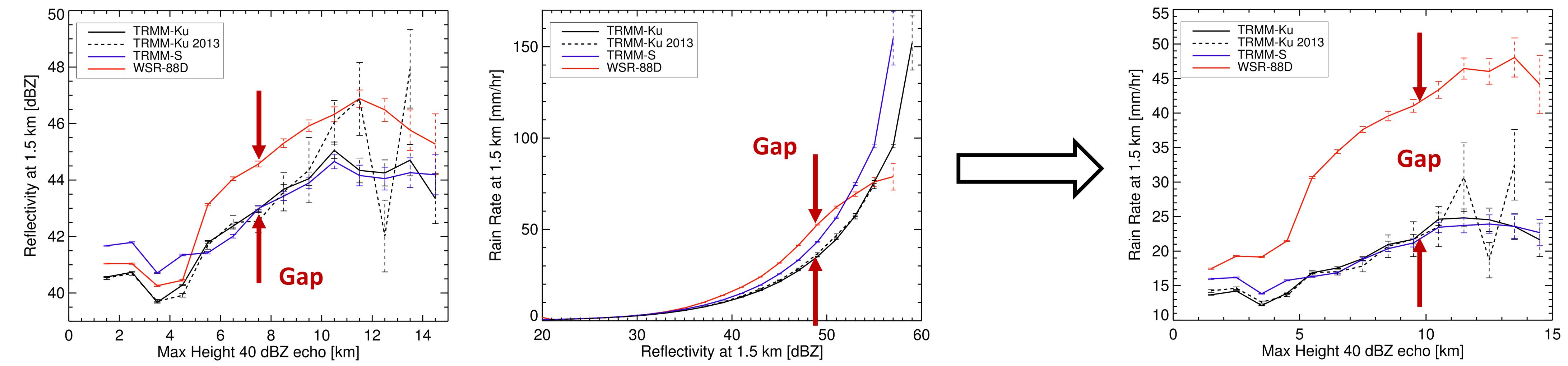


To make comparisons between TRMM and WSR-88D, individual columns need to be considered rather than entire systems, and these also show a low overlap fraction across the tropics and subtropics, as shown above.

June-August (JJA) 2013 data from 28 dual-polarimetric WSR-88D radars over the SEUS are Cartesian gridded at 1.125 km horizontal and 250 m vertical spacing. Rain rates are retrieved using the CSU-HIDRO algorithm that situationally chooses between Z-R, Z-ZDR, Z-ZDR-KDP, and Z-KDP relationships (Cifelli et al. 2013). Data is averaged down to 4.5 km horizontal spacing to approximately match the TRMM resolution. To include entire columns, data are limited to between 40 and 80 km ranges from each radar. JJA 2002-2013 TRMM 2A25 V7 retrievals within 80 km range of each of the WSR-88D radars is converted from Ku-band to S-band using the conversion factors in Cao et al. (2013) – rain below 4-km altitude and hail above 5-km altitude. The greater of the TRMM and WSR-88D sample sizes for each radar are randomly sub-sampled to the lesser sample size so that sample sizes are equal for each of the 28 radars considered.

Comparisons focus on 1.5-km altitude reflectivity, 1.5-km altitude rain rate, and maximum 40 dBZ echo height. TRMM path integrated attenuation (PIA), as well as WSR-88D differential reflectivity (ZDR), specific differential phase (KDP), and hail fraction (areal fraction of hail, graupel, and mixed hail/rain points from particle identification algorithm) are also explored.

3. SOUTHEASTERN US TRMM VS. WSR-88D RELATIONSHIPS

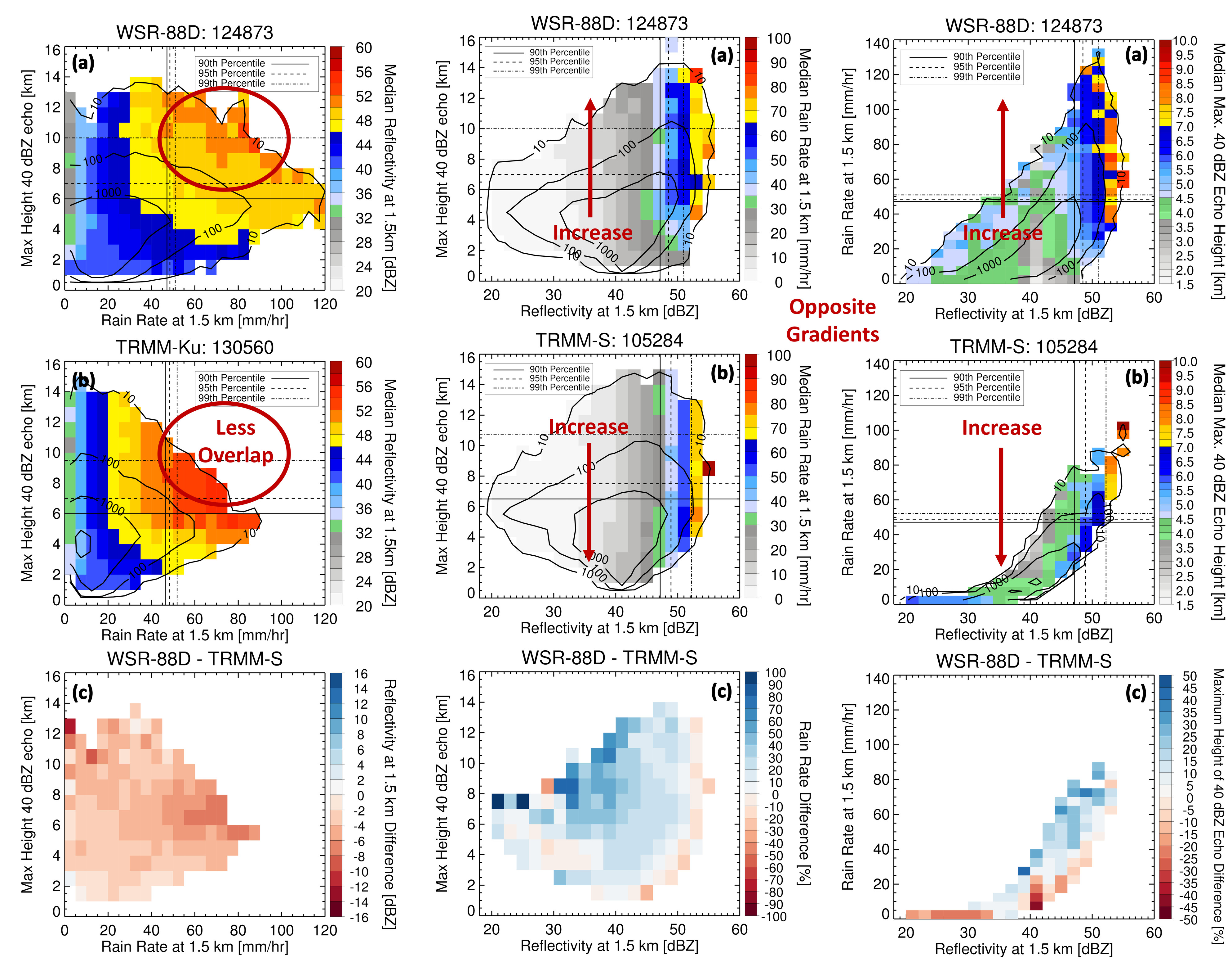


For a given maximum 40 dBZ height above 5 km, mean WSR-88D 1.5-km altitude reflectivity is consistently 1.5 dB greater (left). Retrieved mean rain rates for reflectivities < 52 dBZ are also greater (middle). These differences combine to produce WSR-88D mean rain rates that are nearly double those of TRMM for a given maximum 40 dBZ height. TRMM retrievals from 2013 alone when WSR-88D retrievals are used show that 2013 is likely not an anomalous summer relative to the 2002-2013 period from which TRMM retrievals are used.

4. REFLECTIVITY VS. RAIN RATE VS. MAXIMUM 40 DBZ HEIGHT

In the leftmost column below, max. 40 dBZ height-1.5 km rain rate joint histograms are filled with median 1.5 km reflectivity. Extreme rain rates occur most frequently for max. 40 dBZ heights of ~6 km, but the overlap of extreme max. 40 dBZ heights and rain rates is ~50% greater for WSR-88D than TRMM. TRMM has greater median 1.5 km reflectivities for all max. 40 dBZ height-rain rate combinations.

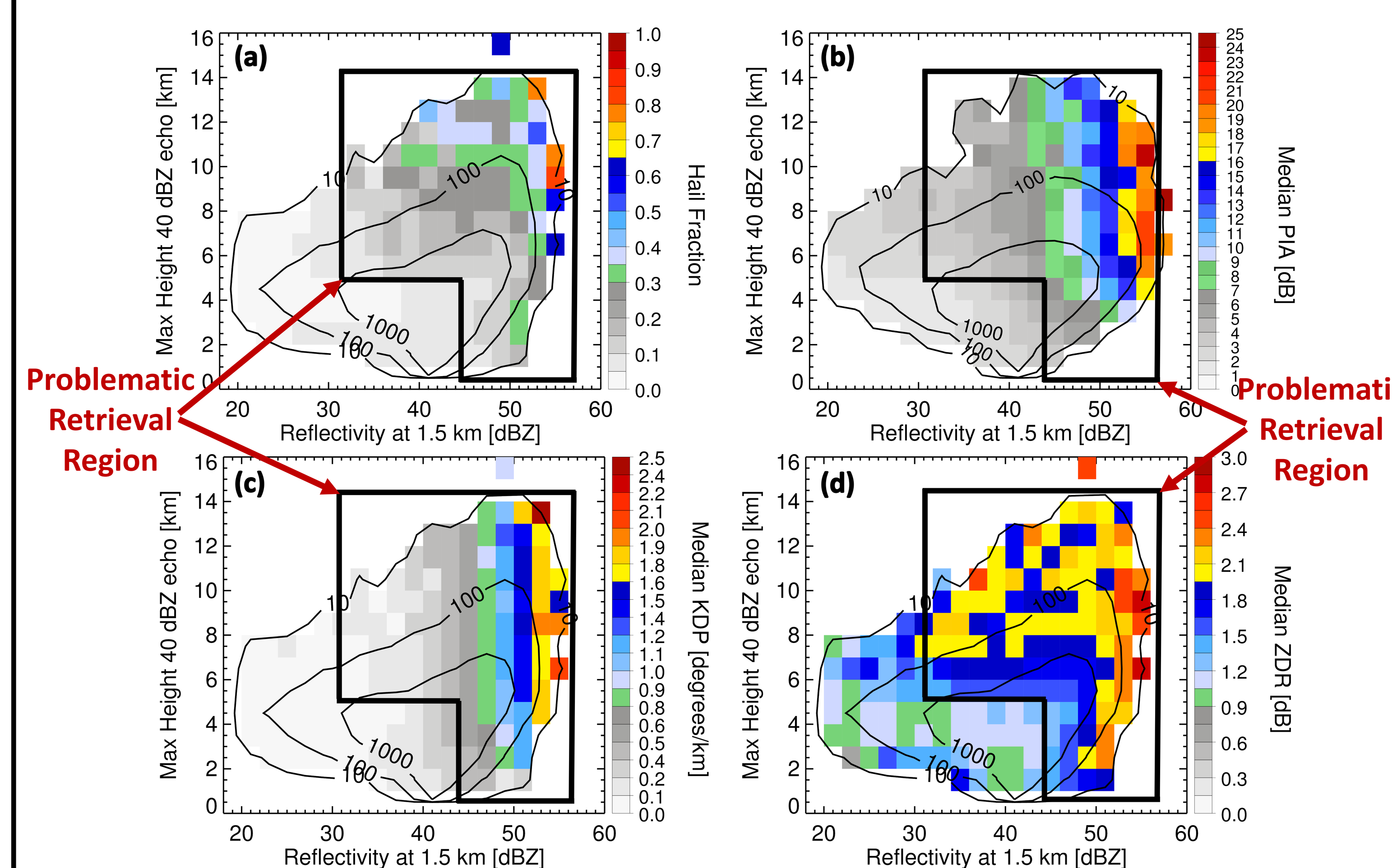
In the middle column below, max. 40 dBZ height-1.5 km reflectivity joint histograms are filled with median 1.5 km rain rate. TRMM rain rates are up to 70% lower than WSR-88D for max. 40 dBZ heights above the melting level and moderate 1.5 km reflectivities. For a given 1.5 km reflectivity, WSR-88D rain rate increases with max 40 dBZ height, but the opposite is true for TRMM.



In the rightmost column above, 1.5 km rain rate-reflectivity joint histograms are filled with median max. 40 dBZ height. WSR-88D rain rates are more variable than TRMM for a given reflectivity, and TRMM max. 40 dBZ heights decrease as rain rate increases for a given 1.5 km reflectivity. WSR-88D exhibits the opposite pattern.

5. PIA, KDP, ZDR, AND HAIL FRACTION

TRMM-observed extreme max 40 dBZ heights and 1.5 km reflectivity exhibit significant PIA, making those columns vulnerable to retrieval error. WSR-88D KDP slightly increases with max. 40 dBZ height for a given 1.5 km reflectivity, but ZDR significantly increases when max. 40 dBZ height exceeds 5 km. Additionally, estimated 1.5 km hail fraction increases significantly above 5 km. These patterns collectively indicate that 1.5 km particle size distributions are likely unique for situations of significant hail or graupel aloft signified by elevated 40 dBZ echoes.



6. CONCLUSIONS

Comparison of TRMM with WSR-88D over the SE US confirm a low overlap fraction between the most extreme rain rates and convective intensities, but the overlap is ~50% higher in WSR-88D retrievals because low level reflectivity and rain rate are higher for max 40 dBZ heights exceeding 5-km altitude when graupel or hail are likely present aloft. Relatively large PIA, ZDR, KDP and hail fraction values for 1.5 km reflectivities exceeding ~45 dBZ or maximum 40 dBZ heights exceeding ~5-km altitude, indicating unique particle size distributions that may be different than what is assumed in TRMM 2A25 V7, in which phase and size distribution profiles need to be assumed. Incorrect phase and size distributions combined with potentially incorrect PIA estimates in these convectively intense situations may produce low biased near-surface TRMM attenuation-corrected reflectivities and rain rates, while assumed Z-R relationships may further increase rain rate low biases. Results have been submitted to the Journal of Applied Meteorology and Climatology.

REFERENCES: Cao, Q., and coauthors, 2013: Empirical conversion of the vertical profile of reflectivity from Ku-band to S-band frequency. *J. Geophys. Res.*, *118*, 1814–1825.
Cifelli, R., and coauthors, 2011: A new dual-polarization radar rainfall algorithm: Application in Colorado precipitation events. *J. Atmos. Oceanic Tech.*, *28*, 352–364.
Hamada, A., Y. N. Takayabu, C. Liu, and E. J. Zipser, 2015: Weak linkage between the heaviest rainfall and tallest storms. *Nature Communications*, *6*, 6213.

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