TRMM Measurements of Precipitation Systems with Extreme Rain Rates and Extreme Intensities

Alexandria C. Gingrey, Adam C. Varble, & Edward J. Zipser

Department of Atmospheric Sciences, University of Utah, Salt Lake City, UT

Motivation & Background

The attenuation correction in the TRMM Precipitation Radar algorithms is known to have uncertainties, and those uncertainties are likely greatest for intense storms with high path integrated attenuation (Iguchi et al. 2009). For a given reflectivity, there exists as much as a factor of four difference in estimated near-surface rain rates. Our goal is to investigate potential bias in near-surface reflectivity and rain rate retrievals across the spectrum of convective intensity.

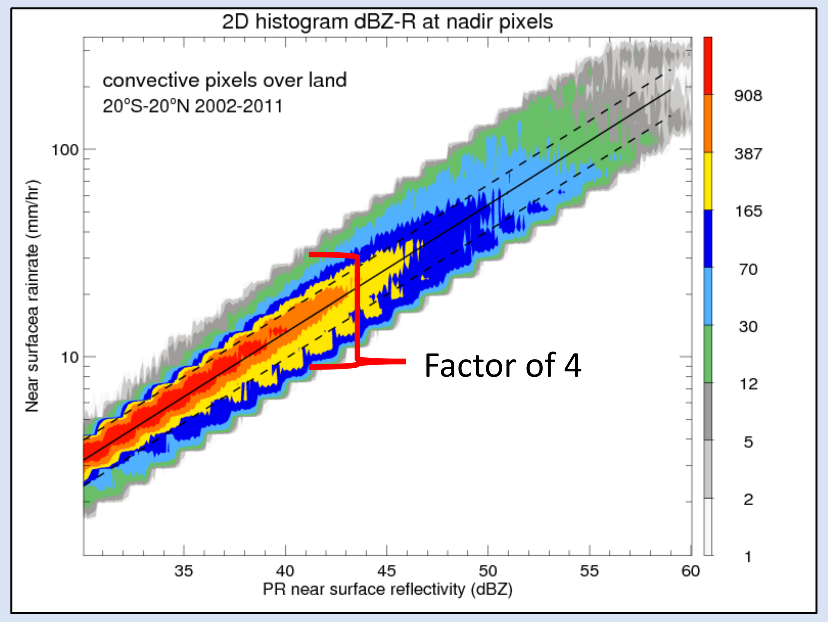

Figure 1. Relationship between TRMM V7 2A25 attenuation-corrected near-surface reflectivity and near-surface rain rate. Figure from Liu (2013).

Data & Methods

- Data used:
  1. University of Utah TRMM Database (Liu 2009) version 7 precipitation features and level one data columns from post-boost era [2002-2013] throughout the tropics as well as over the Southeastern United States (SEUS) domain [30,34,-89,-82]
  2. WSR-88D data over the SEUS domain [30,34,-89,-82] limited to convective scans between 40 and 80 km from radars gridded to match TRMM resolution
- Columns with reflectivities of 20 dBZ and higher at 1 km are saved from both the TRMM and WSR-88D archives
- The tropics domain is split into 5° x 5° boxes. Within each box, statistics are calculated to determine the top 0.5th percentile of the following variables:
  1. Top 0.5% of maximum 40 dBZ echo heights
     a. Proxy for 'convectively intense' (Zipser 2006)
  2. Top 0.5% of maximum near surface rain rate
     a. Proxy for 'extreme rainfall'
- Using the top 0.5th percentile reduces the dataset to 'extreme' precipitation features without unduly restricting sample size

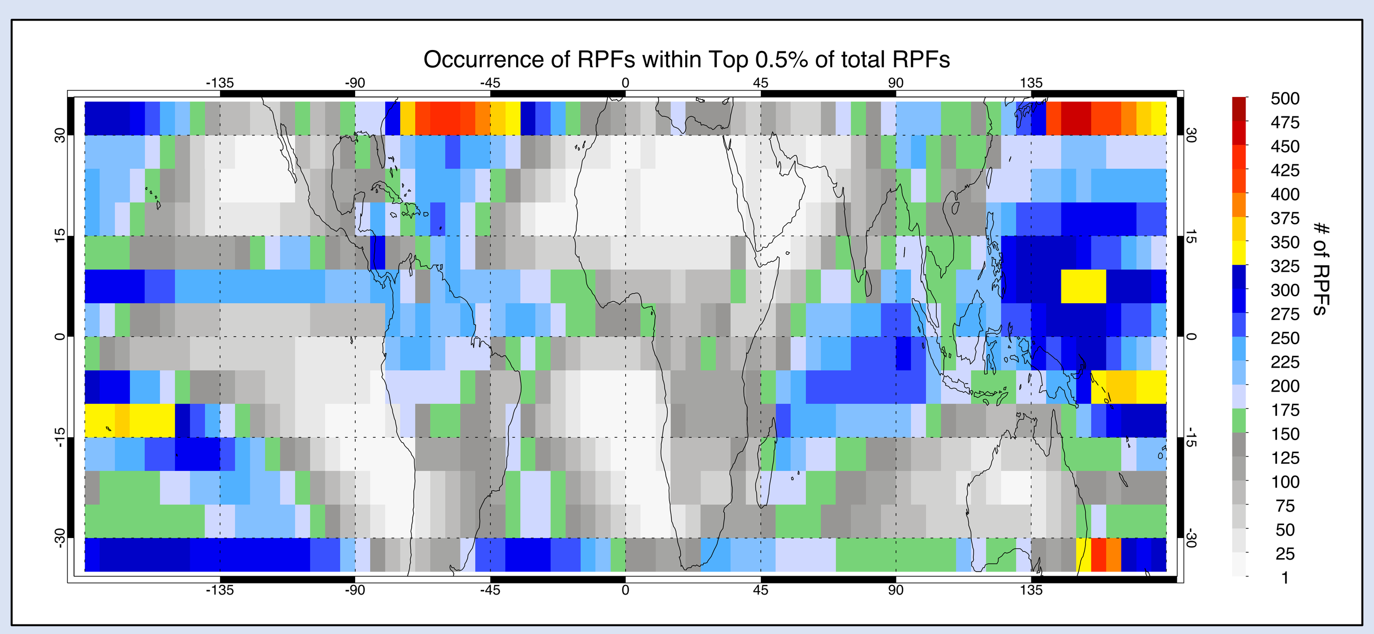

Figure 2. Number of RPFs in the top 0.5th percentile for each 5° x 5° grid box between 35°S and 35°N using TRMM data from 1999-2012.

Highest feature totals exist along the boundaries of the domain due to TRMM's orbit. We don't correct for this because our analyses are restricted to each individual grid box, thus this oversampling does not affect the results. Regions of less influence exist in the subsidence zones throughout the subtropics.

General look at Precipitation Feature Characteristics

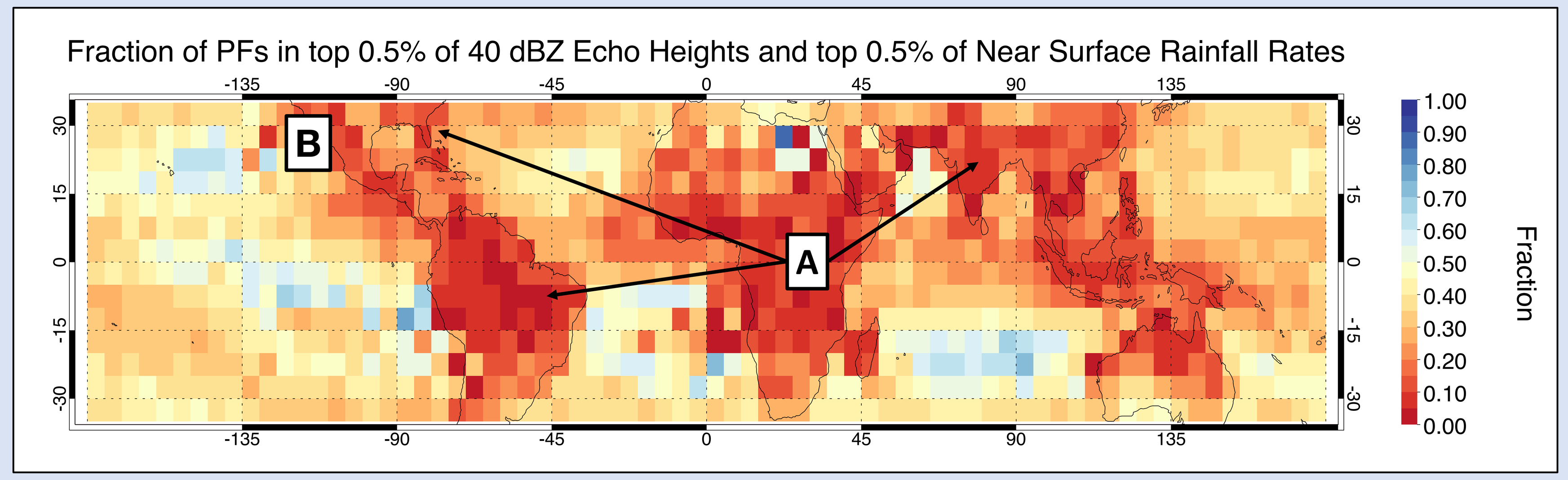

Figure 3. Distribution of the fraction of precipitation features that exist in the top 0.5th percentile of both maximum 40 dBZ echo heights and near-surface rain rates.

A. There is little correspondence between precipitation features with top rain rates and the top 40 dBZ echo heights over land. Areas of higher correspondence are located over the oceans, especially where the echo tops are lower.

B. While the precipitation feature overlap fraction is smaller over land than over ocean, the Southeastern United States has a non-negligible overlap fraction as well as sample size (Figure 2), making it a good location to examine the veracity of these low fractions.

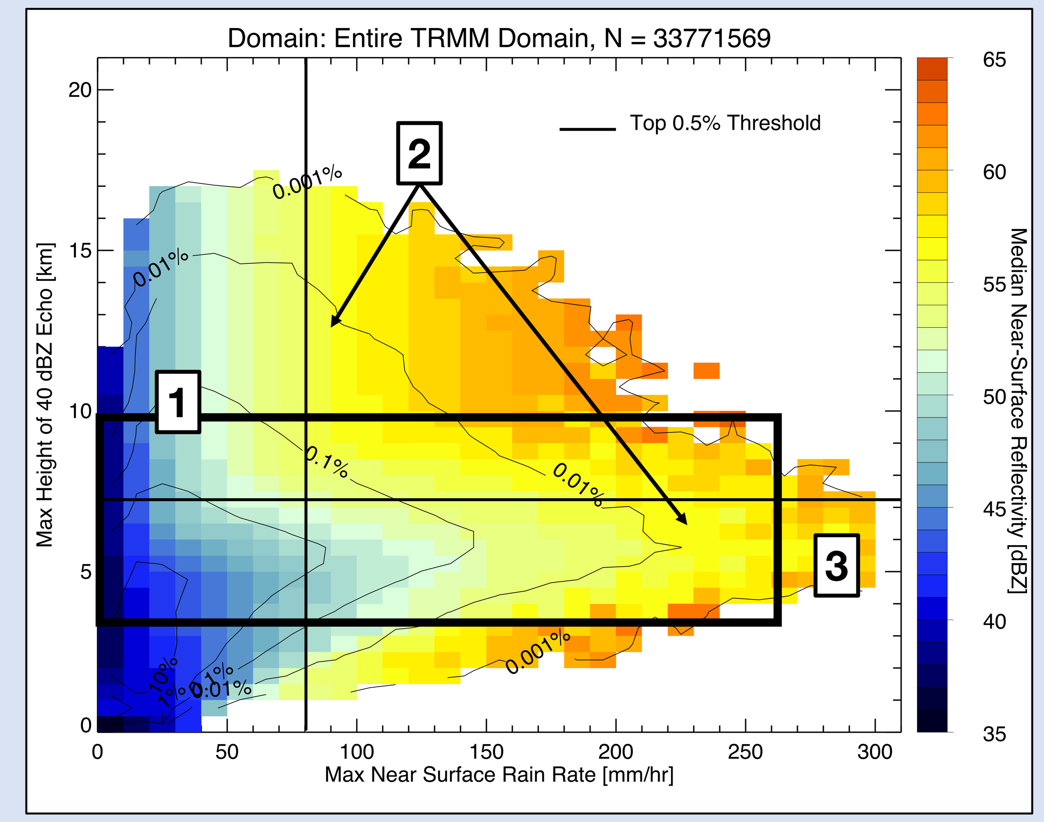

Figure 4. Joint histogram of maximum 40 dBZ echo heights and maximum near-surface rain rates filled with the median of maximum near-surface reflectivity for all precipitation features.

1. Precipitation features with higher maximum 40 dBZ echo tops have greater maximum near-surface reflectivities for a given rain rate.

2. For a given maximum near-surface reflectivity, multiple possibilities exist for corresponding maximum near surface rain rates and 40 dBZ echo heights.

3. Precipitation features with intense rain rates have the highest probability of having a maximum 40 dBZ echo top height near 5 km. This is a counter-intuitive result that requires further investigation.

Preliminary Results – TRMM v. WSR-88D in SEUS Domain

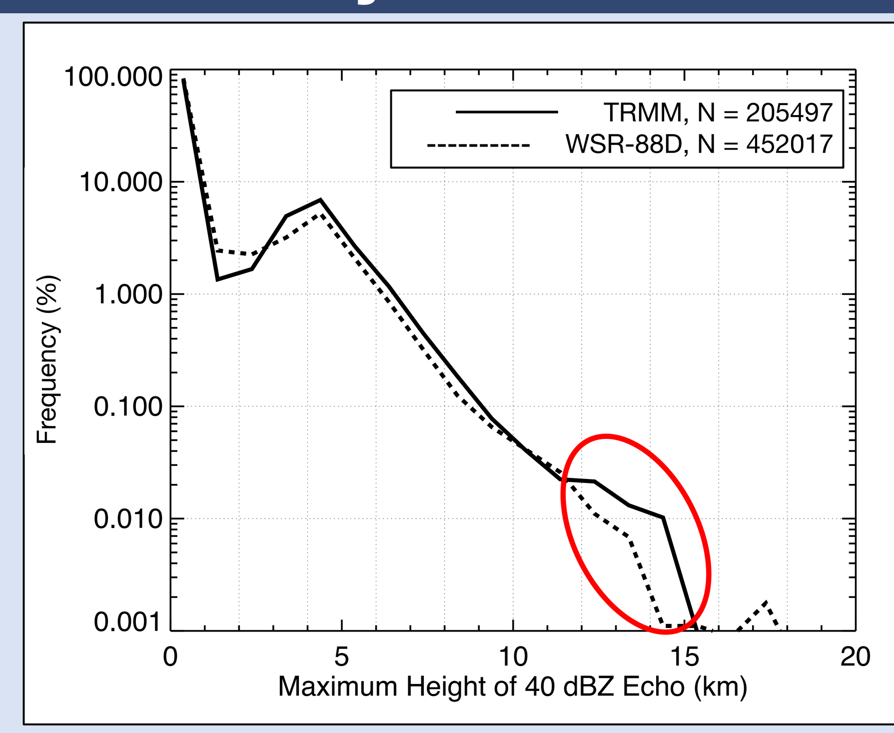

Figure 5. PDF showing the probability of occurrence of maximum 40 dBZ heights from TRMM (June, July, and August 2002-2013) and WSR-88D (June, July, and August 2013) datasets.

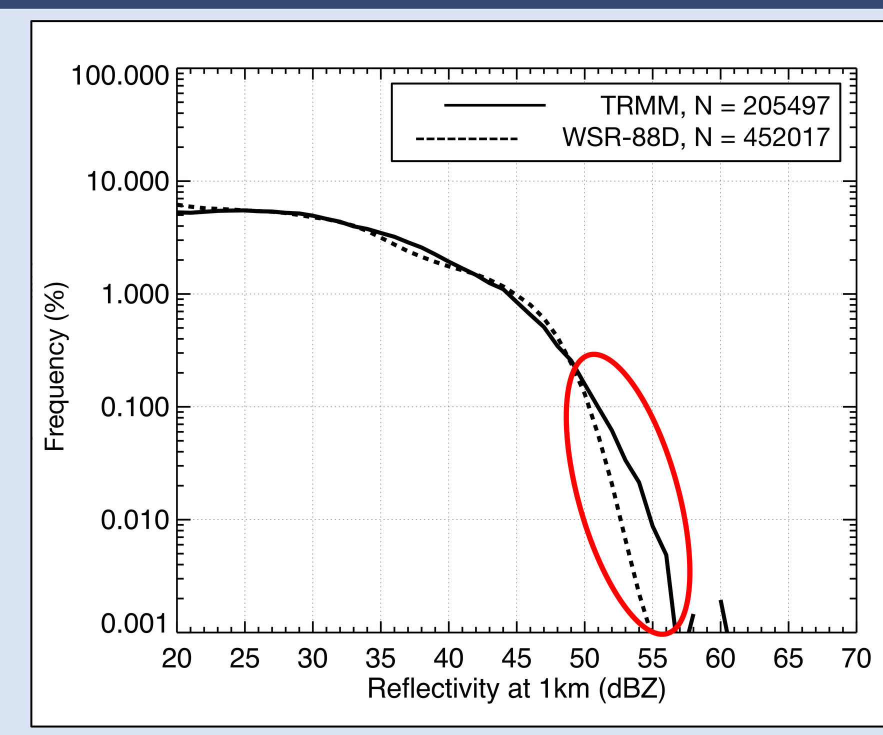

Figure 6. PDF showing the probability of occurrence of 1-km reflectivities from TRMM (June, July, and August 2002-2013) and WSR-88D (June, July, and August 2013) datasets.

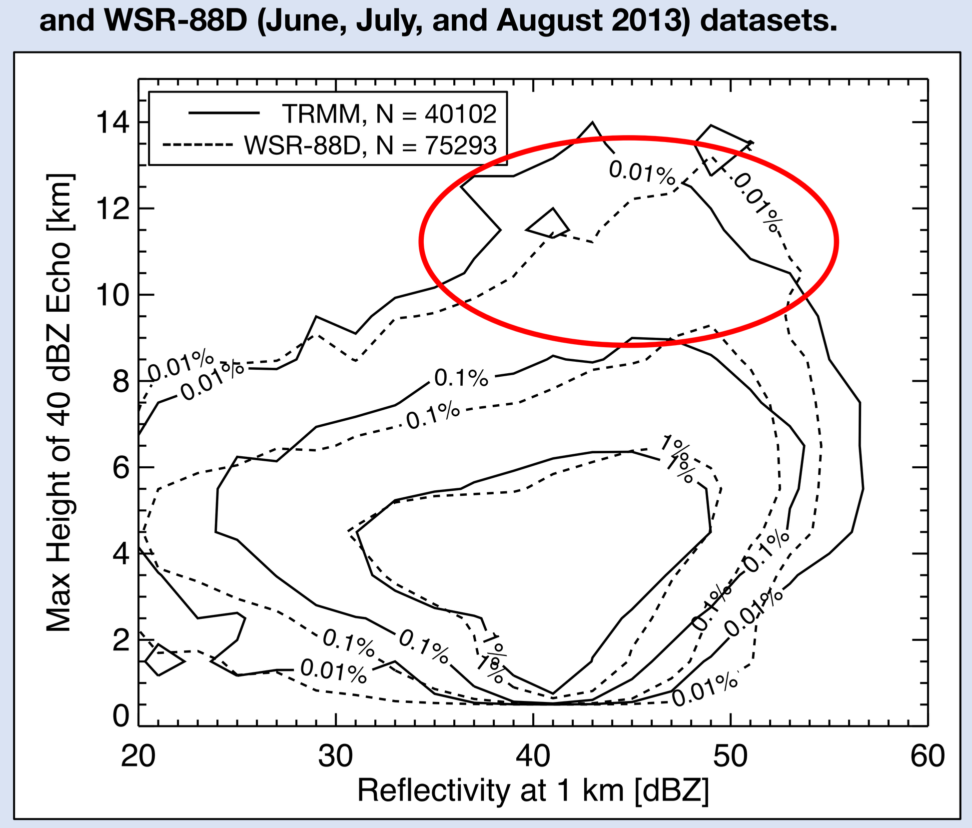

Figure 8. Joint Histogram of maximum 40 dBZ heights and 1-km reflectivity for TRMM (June, July, and August 2002-2013) and WSR-88D (June, July, and August 2013) datasets. Contours express the percentage of the respective dataset.

- TRMM and WSR-88D exhibit similar distributions of maximum 40 dBZ echo height. WSR-88D has a lower percentage of 12+ km maximum 40 dBZ echo heights than TRMM. This needs further investigation through a comparison of the WSR-88D scan strategies, as the scan type could be affecting this result.
- TRMM measures more high reflectivity values at 1-km altitude than WSR-88D. However, for both datasets, these larger reflectivities make up a small percentage of the total sample.
- TRMM and WSR-88D relationships between maximum 40 dBZ heights and 1-km reflectivity diverge for high maximum 40 dBZ heights with lower reflectivities for TRMM than WSR-88D. This could indicate potential attenuation bias, and needs further investigation.

Next Steps

1. Preliminary results justify a deeper comparison of WSR-88D and TRMM data with more samples across a larger domain that extends to the southern plains, which are currently being incorporated into the analysis.

2. Differing scan strategies of WSR-88D will be compared to quantify potential bias in the vertical reflectivity profiles of the WSR-88D dataset.

3. Vertical reflectivity profiles as measured by WSR-88D and TRMM across the SEUS will be analyzed as a function of maximum 40 dBZ height to identify potential biases in attenuation. A focus will be on the low-level reflectivity slope as a function of height.

4. Impacts of potential reflectivity biases on 2A25 retrieved rain rates will be quantified using the comparisons between TRMM and WSR-88D.

5. WSR-88D dual-polarimetric rain rate retrievals will be compared with maximum 40 dBZ heights to check whether independent datasets validate the low overlap fraction produced by TRMM retrievals.

References

Iguchi, Toshio, and coauthors, 2009: "Uncertainties in the rain profiling algorithm for the TRMM precipitation radar." *Journal of the Meteorological Society of Japan, 2nd Ed.*, 1-30.

Liu, Chuntao, and coauthors, 2013: "Extreme Rainfall Rates: An Extreme Retrieval Challenge." *American Geophysical Union Fall Meeting,* San Francisco, CA.

Zipser, Edward J., and coauthors, 2006: "Where are the most intense thunderstorms on Earth?" *Bulletin of the American Meteorological Society,* 87, 1057-1071.

Acknowledgements

This research was supported by:
National Aeronautics and Space Administration Grant NNX13AF87G under leadership of Ramesh Kakar

contact: alexandria.gingrey@utah.edu