TRMM precipitation analysis in extreme storms in South America: Underestimation of near-surface rain

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Introduction

- The Tropical Measuring Mission (TRMM) satellite has provided insight into the distribution of precipitating storms in remote tropical and subtropical region of the world
- The TRMM Precipitation Radar (PR) has demonstrated that subtropical South America is home to some of the most intense deep convection in the world (Zipser et al. 2006)

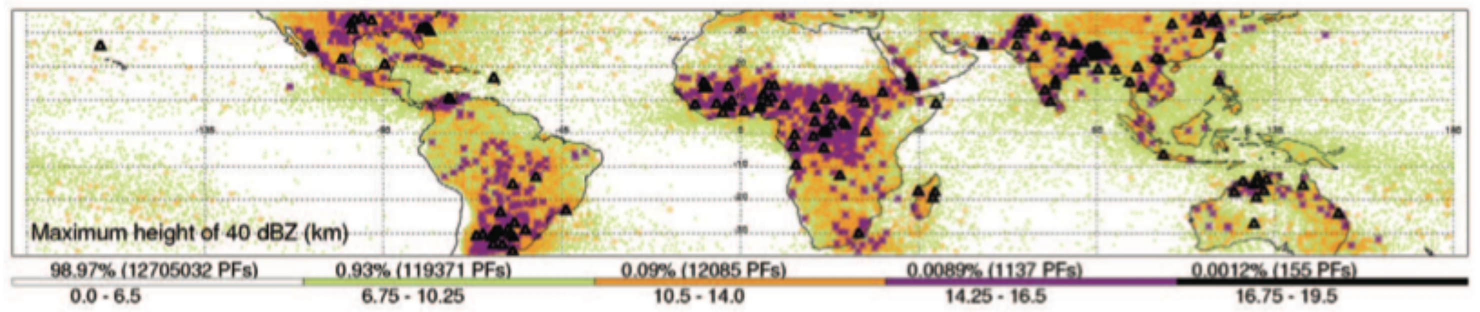


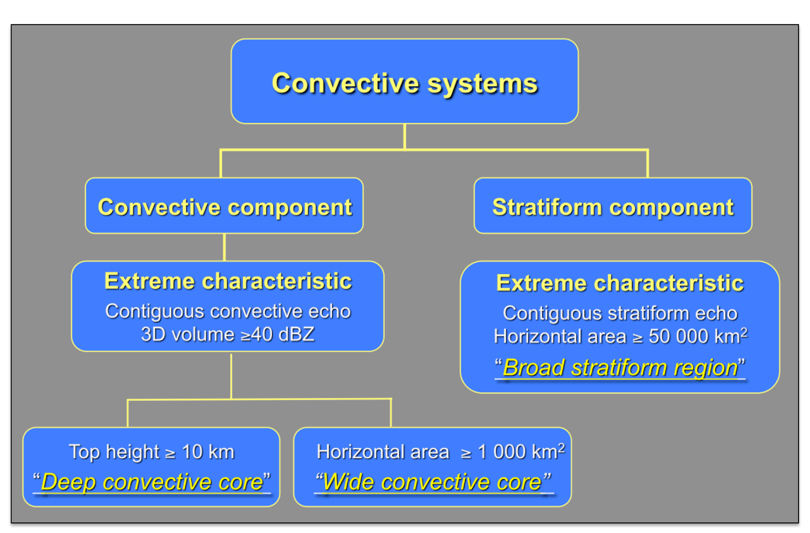
Fig. 1 Locations of intense convective events using the color code matching their rarity, Zipser et al. (2006).

- In addition, South American mesoscale convective system (MCS) cloud shields are 60% larger than those over the United States (Velasco and Fritsch 1987) and they have larger precipitation areas than those over the United States or Africa (Durkee et al. 2009)
- Thus, it is important to understand the impact of precipitation in South America and investigate potential biases in the precipitation distribution associated with the TRMM Precipitation Radar rainfall algorithm

➢ **A systematic bias in the amount and intensity of precipitation has the potential to lead to improper precipitation analyses and biased hydrological impacts, which would preclude accurate forecasting and proper climate modeling in this region of the world**

Background

- UW methodology to separate TRMM Precipitation Radar (PR) echoes into three storm types (Houze et al. 2007): *deep convective cores, wide convective cores*, and *broad stratiform regions*



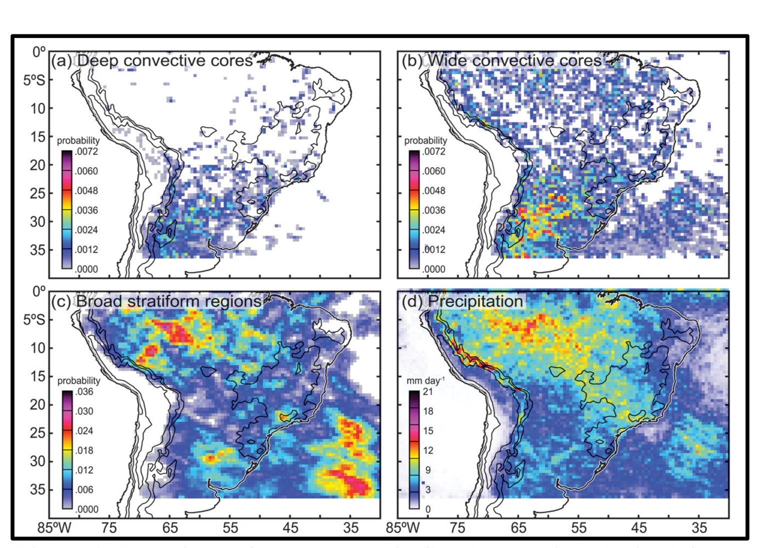


Figure 2. Locations of storm types in South America derived from TRMM PR data. From Romatschke and Houze (2010)

Storm evolution hypothesis presented in Romatschke and Houze (2010) and Rasmussen and Houze (2011):

- Deep convective cores initiate along Andes foothills
- Convection grows upscale, develops wide convective cores, and moves eastward
- Decaying convective elements move farther eastward and develop broad stratiform regions

Extreme convection is often initiated when the South American low-level jet (SALLJ) funnels warm and moist air southward along the foothills of the Andes (Romatschke and Houze 2011 and Rasmussen and Houze 2011)

TRMM Precipitation Radar

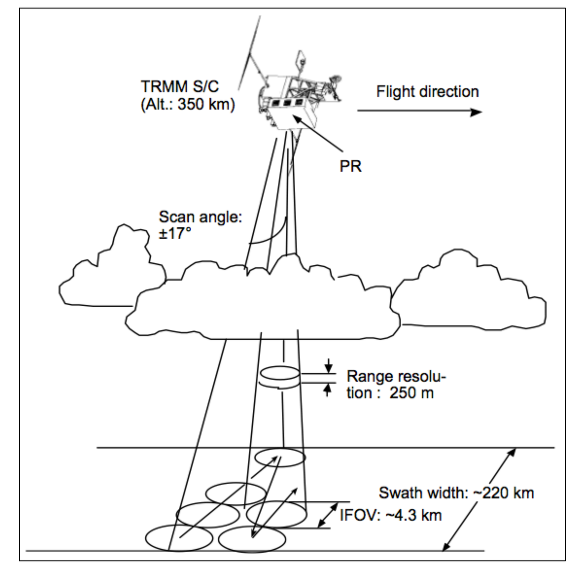


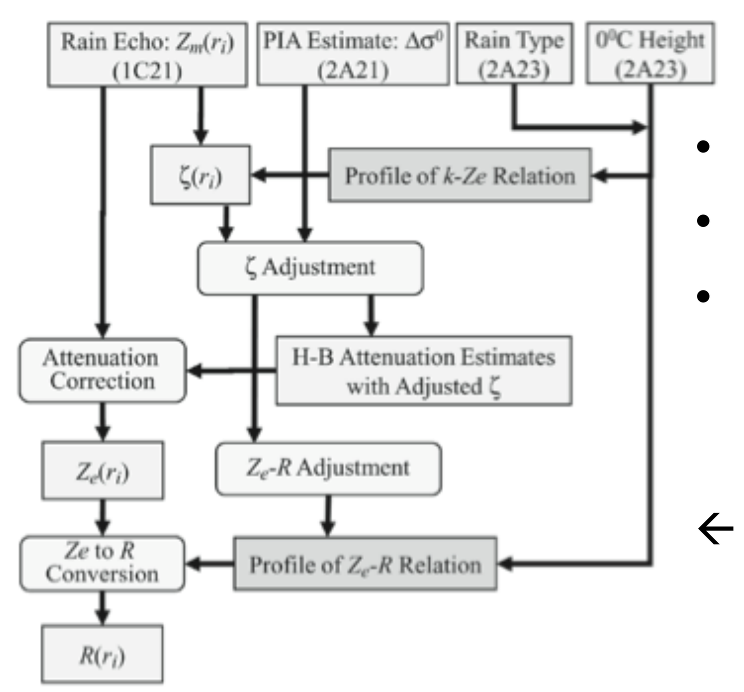
Fig. 3 PR observation concept, TRMM V6 Manual.

- First space rain radar (Kummerow et al. 1998)
- Covers 37.5°N-S across all longitudes and has approximately 16 orbits per day
- Operates at 13.8 GHz
- Minimum detectable reflectivity ~17 dBZ
- Resolution: 0.05°x0.05°, i.e. 5km x 5km

Precipitation rates are determined by an algorithm that is described in detail below

Z-R Relation: Reflectivity to Rain Rate

TRMM rain profiling algorithm



2A25 Algorithm

- Attenuation correction
- Selection of default drop size model
- Correction for non-uniform beam filling effects (Iguchi et al. 2000)

← **Fig. 3** Simplified flow chart of rain profiling algorithm of 2A25, Iguchi et al. (2009).

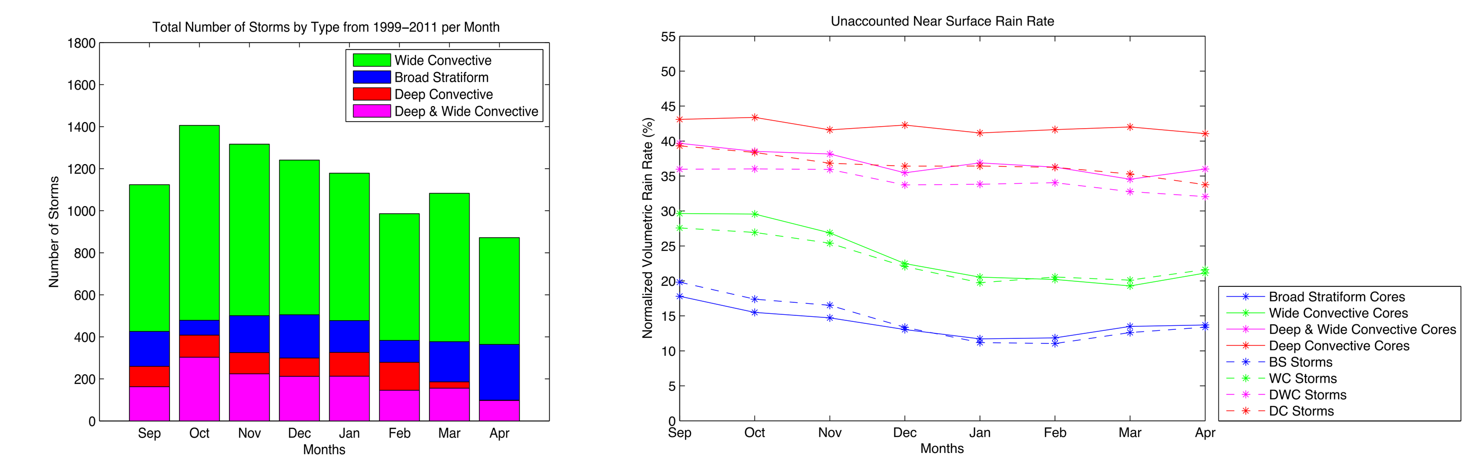
- Drop size distribution (DSD) parameter, epsilon, is an adjustment factor that corrects the measured reflectivity rate to derive the effective (adjusted) reflectivity (Z) in $R = aZ^b$
- Small epsilon implies a large **a** factor → smaller R and rain rate
- Kozu et al. 2009 have further shown that epsilon is negatively correlated with storm-top height and lightning flash rate
- **Algorithm underestimates precipitation in regions of intense deep convection over land** (Iguchi et al. 2009)!

Houze Group Algorithm

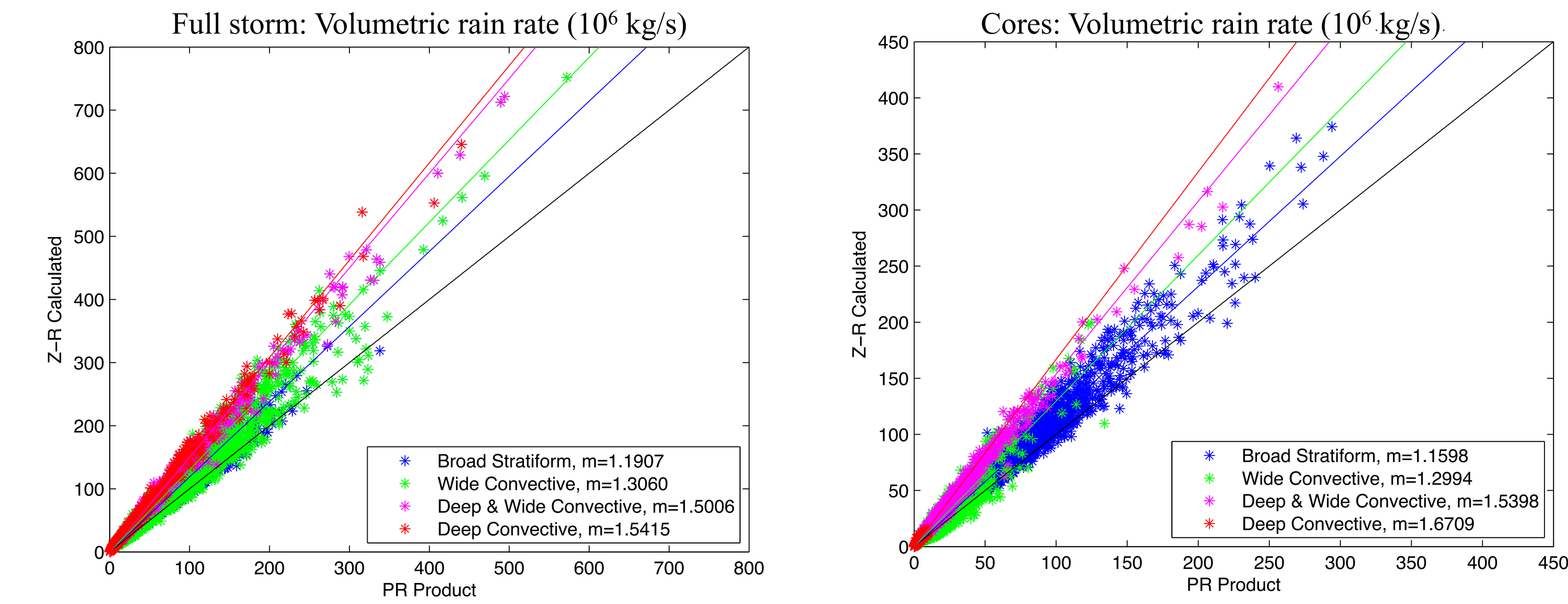
- Rain rates derived from the fine grid (0.05° x 0.05° horizontal and 0.25km vertical resolution), employing the relation: $R = (Z / a)^{1/b}$
- Rain rates are set to 0 if the lowest height of positive reflectivity value and underlying surface are 2.5+ km apart, as it is unlikely precipitation from these altitudes will reach the surface
- Techniques similar to this are used for ground-based radar rain estimates

Z	interpolated reflectivity for a grid point in a convective system
R	Rain rate
a, b	Constants adjusted according to rain type

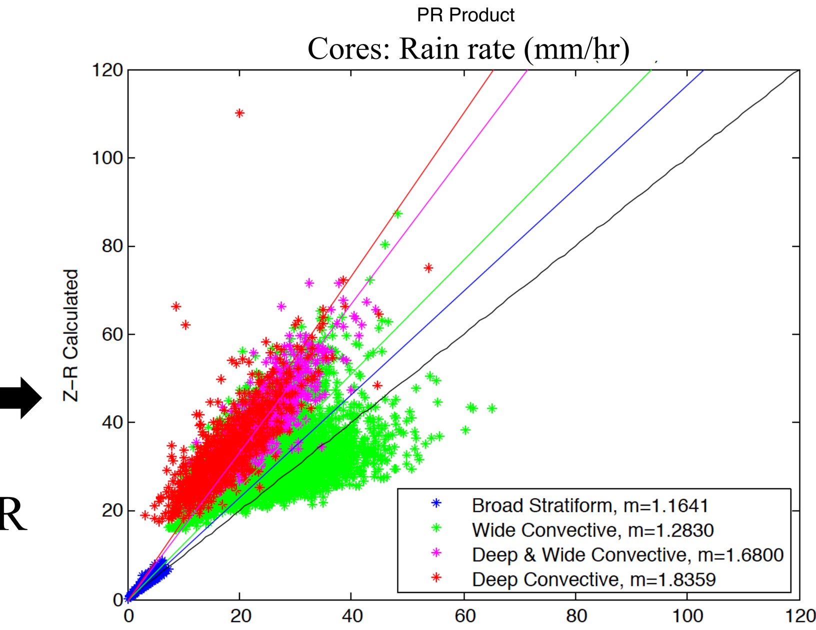
Rain estimation method comparison



- There is a positive relationship between rain rate underestimation and convective intensity, independent of season
- Up to **40%** in volumetric rainfall rate is unaccounted for in deep convective storms



- Deep convective storms exhibit the largest underestimation of surface precipitation from the TRMM PR algorithm (compared to the Houze group method)
- Instantaneous rain rates (mm/hr) ➡ within the echo cores demonstrate the biases induced by the TRMM PR algorithm for convection over land!



Conclusions

- Compared to a more traditional Z-R calculation of precipitation, the TRMM PR near-surface rain product generally underestimates the volumetric and instantaneous rain rates in all storm categories
- The underestimation gets worse as the storms become deeper and more intense, especially over land (increasing slope with convective intensity)
- Rain rate estimation is highly sensitive to the attenuation correction, the DSD, and microphysical parameters used in the TRMM algorithm
- Systematic miscalculation of the precipitation rates over land can give rise to large biases that are important to consider when using TRMM precipitation products to validate weather and climate models, investigate extreme precipitation events, global precipitation estimates, hydrological impacts, and many other relevant applications

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