Examining Regime Dependency of Z-R relationships: Observations from Kwajalein, RMI

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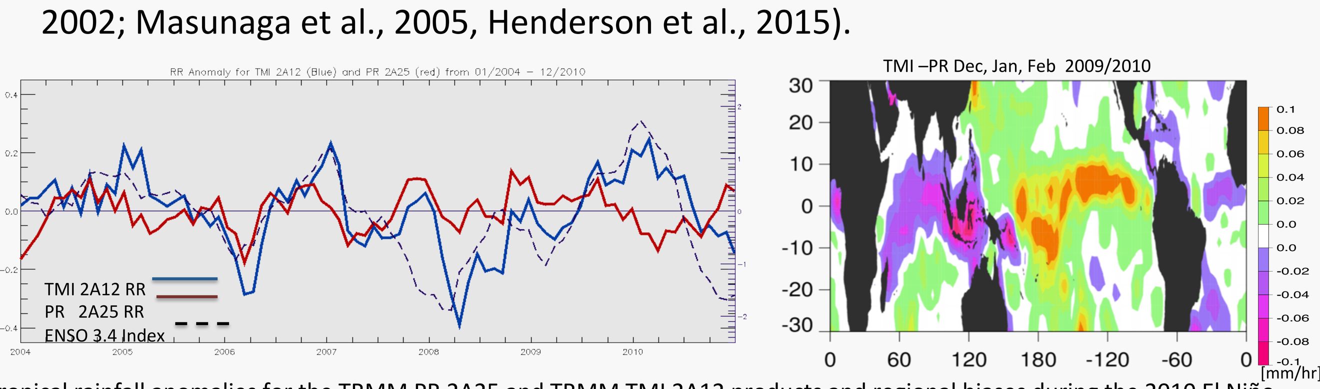
Introduction

- Ground validation (GV) data is an excellent resource to assess TRMM and GPM rainfall retrievals.
  - Aid in understanding variability in the TRMM rainfall record. Discrepancies between PR and TMI exists in the TRMM oceanic tropical rainfall time series associated with systematic shifts in precipitation regimes associated with ENSO (e.g. Berg et al., 2002; Masunaga et al., 2005, Henderson et al., 2015).

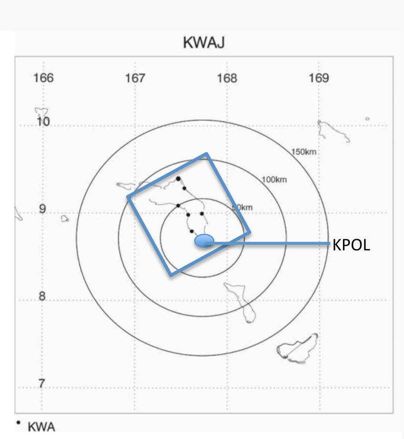


Tropical rainfall anomalies for the TRMM PR 2A25 and TRMM TMI 2A12 products and regional biases during the 2010 El Niño.

  - Evaluate regime-dependent biases between the GPM DPR and GMI retrievals. Consistent GV will be needed to evaluate the increased information content in the DPR retrievals as well as the varying levels of information content from the multiple radiometers in the GPM constellation.
- Oceanic retrievals are more difficult to assess due to a smaller number of observations and heavily relies on the KPOL radar at Kwajalein, RMI. Currently, the Kwajalein GV program retrieves rainfall using a single, annual Z-R relationship derived using the Window Probability Matching Method (WPMM) – this methodology is unable to capture seasonal changes in Z-R driven by variation in precipitation regimes.
- The goal of this poster is to demonstrate how Z-R relationships vary in different precipitation regimes during the Kwajalein 2011 wet season (September-November) and test if regime-based Z-R relationships improve rainfall estimates. The results are compared with dual-polarized derived estimates to test if DSD information captures the regime-based variability.

Application of Kwajalein KPOL Data

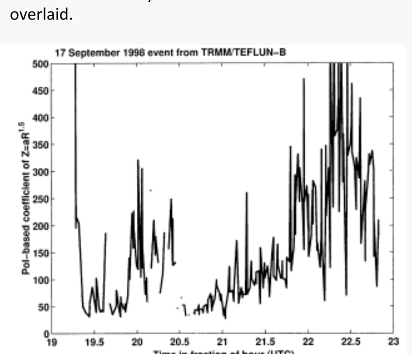
- The KPOL radar is an operational dual-polarized S-band radar located on the Kwajalein Atoll in the Republic of the Marshall Islands. It is one of the few dual-polarized S-band radars located in an open-ocean tropical environment and is an invaluable GV site for comparison of rainfall TRMM and GPM oceanic rainfall retrievals.
- We compare surface rain rate (TRMM 2A53) derived using WPMM to regime-based WPMM derived rain rates and polarimetric rain retrievals provided by D. Marks (personal communication) using the methodology of Bringi et al. (2004). All analysis is conducted within a 1°x1° box centered on the Atoll. The WPMM and polarimetric methods are advantageous as they do not depend on convective/stratiform partitioning.
- Precipitation regimes are defined using a k-means clustering method, applied to the KPOL data using reflectivity (2A55) and precipitation type (2A54), described by Elsaesser et al. (2010). The resultant regimes are defined: *Stratiform, Shallow Convection, Deep Convection, and Deep Organized Convection.*



Gauge locations (Taken from Wolff et al, (2005)). The 1° area of analysis and KPOL radar location are overlaid.

TRMM 2A53 WPMM surface rain rate

A single Z-R relationship is derived annually for 2011 and for the 2011 wet season using the WPMM - matching quality-controlled reflectivities to gauge-estimated rain rates (TRMM 2A56). Regime dependent Z-Rs are developed by first calculating the regime in the defined 1° box for each radar scan during the wet season and then segregating reflectivity and gauge rain rates by regime. The segregated data is used in the WPMM resulting in four precipitation regime Z-R relationships.



Evolution of "a" from $Z = aR^{1.5}$ (Bringi et al (2004))

Dual-Polarized derived rainfall using Bringi et al (2004)

A polarimetrically-tuned Z-R relationship with the assumption of a Z-R relationship in the form:

$$Z = aR^{1.5}$$

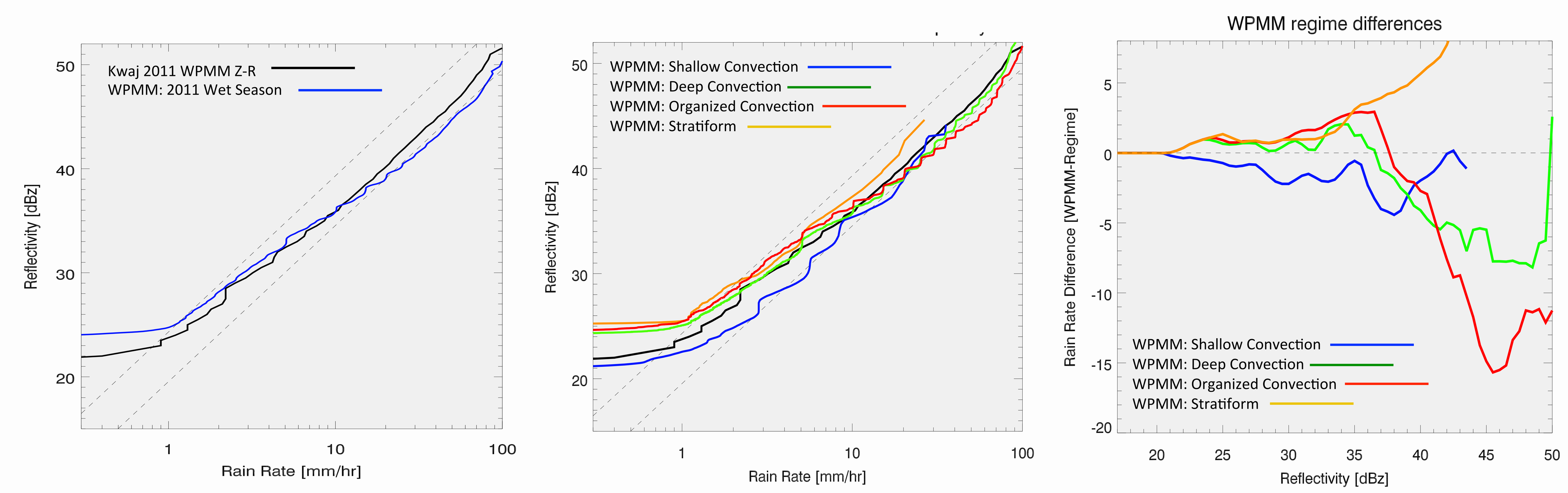
The coefficient, a, is continuously adjusted as the DSD evolves in space and time at each pixel and dynamically determined by the magnitude of observed Z_H, Z_{DR}, and K_{DP}. This methodology does not require rain gauges for tuning or information on the precipitation type.

Precipitation Regime Characteristics

- The Kwajalein wet season contains the regions most frequent observations of heavily raining systems.
  - Shallow and deep convection are most prevalent, but the scattered nature of shallow convection poses sampling issues in the WPMM.
- All regimes meet the requirements to derive a stable Z-R (Rosenfeld et al, 1994).
- Mean values are derived in the 1°x1° box and values in parenthesis are taken from Elsaesser et al (2010).

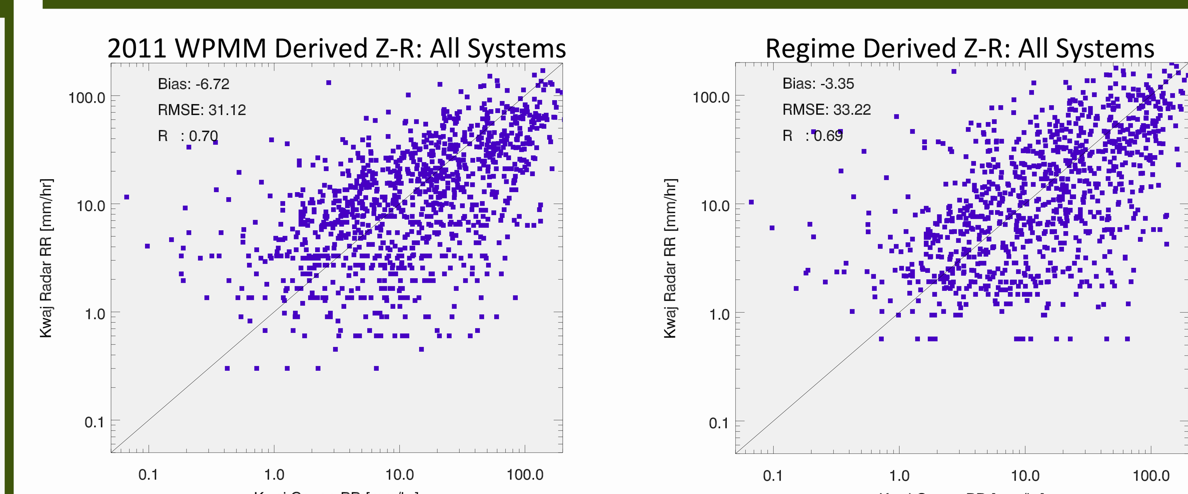
	Total Number Identified	Percent of Total	WPMM Windows used	WPMM Windows with Rain	Total Gauge Accumulation	Mean Rain Rate [mm/hr]	Fraction of Stratiform rainfall
Shallow Convection	3596	32%	468	160	243 mm	3.2 (2.1)	31% (30%)
Deep Convection	4430	40%	3632	1349	1280 mm	13.6 (14.2)	36% (40%)
Organized Convection	1195	11%	1784	765	870 mm	51.4 (53.9)	51% (50%)
Stratiform	1847	16%	1446	461	370 mm	4.1 (--)	85% (--)

Applying the WPMM to Precipitation Regimes



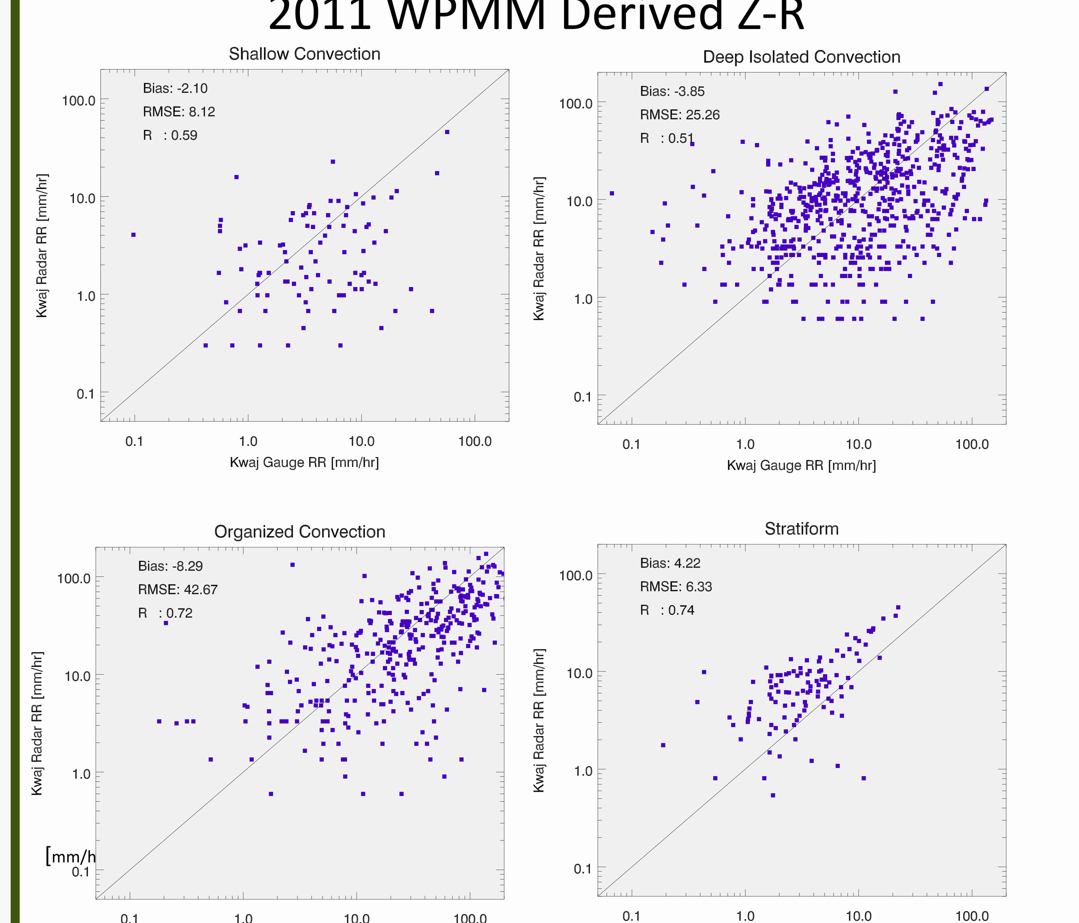
- The above figures illustrate the differences in using the standard annual WPMM to ones specifically derived for the 2011 wet season and individual precipitation regimes. The 2011 WPMM overestimates lighter rainfall, which is usually identified as stratiform rainfall, and heavily underestimates intense convective rainfall for the deep and organized convection regimes. Rainfall from shallow convection is nearly always underestimated.

Comparing Rainfall Estimates to Ground Gauges

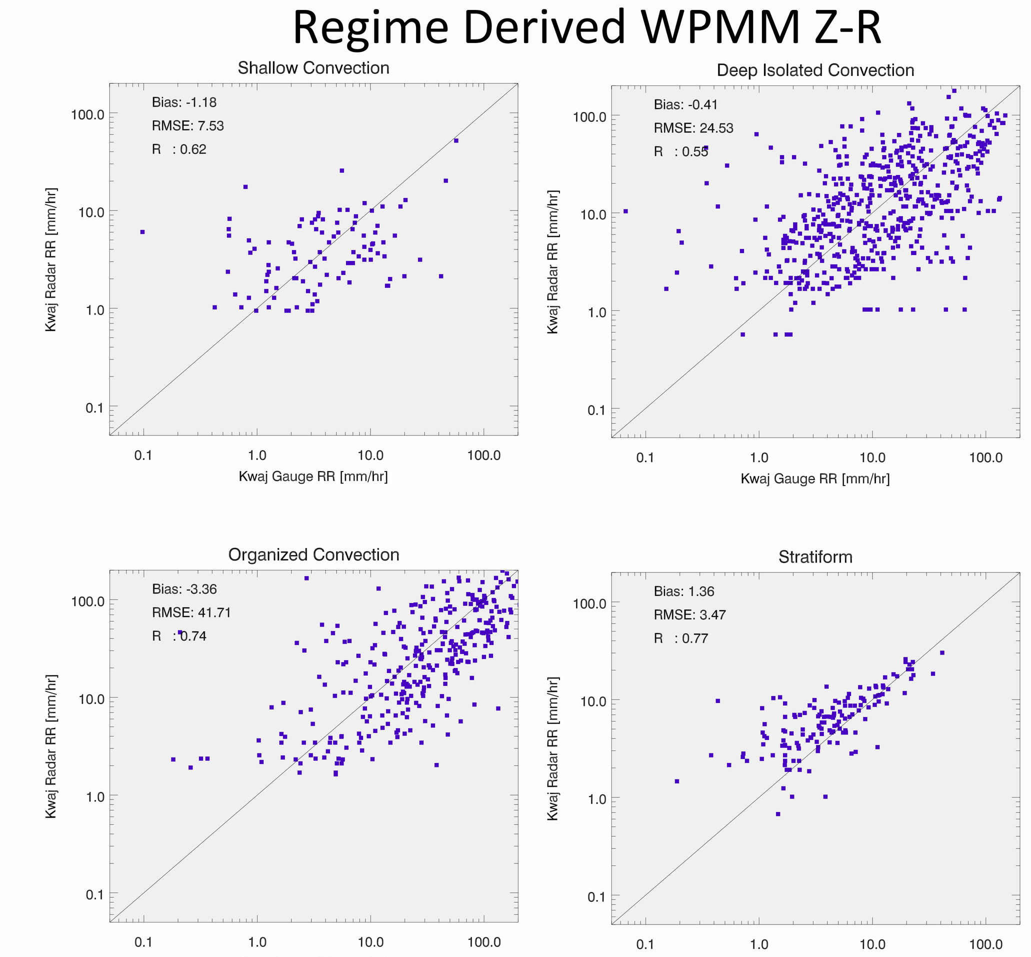


- **Rain rates from the 2011 WPMM and regime-dependent WPMM are compared with rain gauges using the methodology of Wang and Wolff (2009).**
- The general trend of WPMM overestimating low rain rates and underestimating high rates is consistent with the gauge results.
  - The regime dependent WPMM results demonstrate statistical improvement compared to the yearly WPMM – significantly reducing biases with gauges. However, scatter remains and it is clear that DSD variability is still an issue.

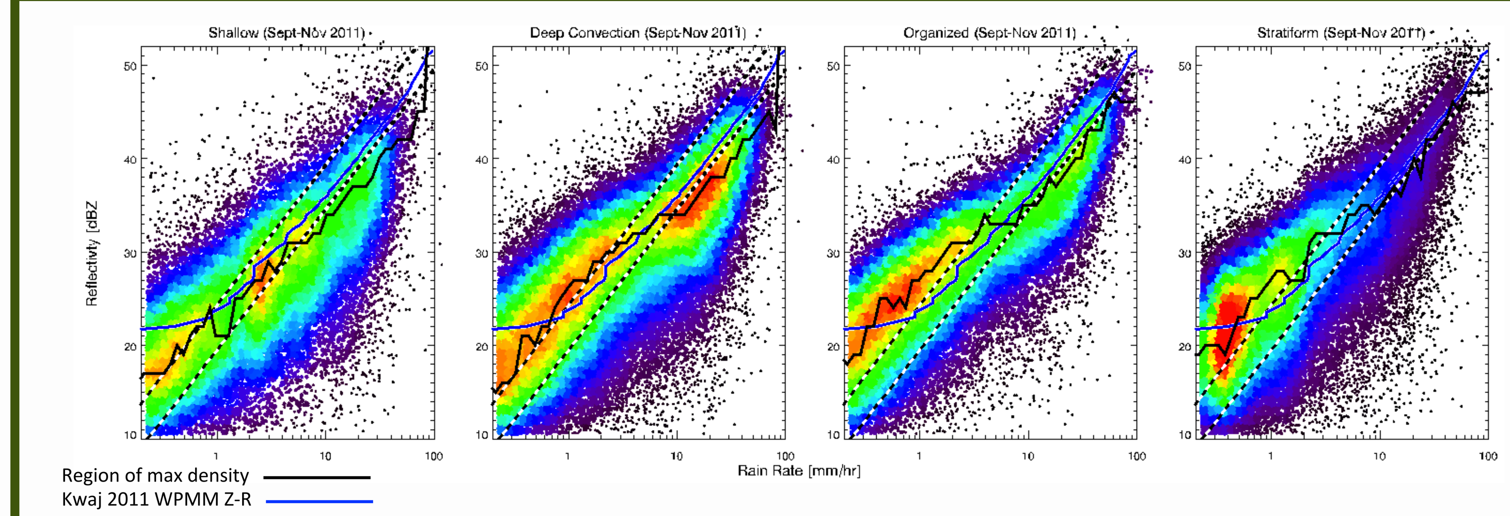
2011 WPMM Derived Z-R

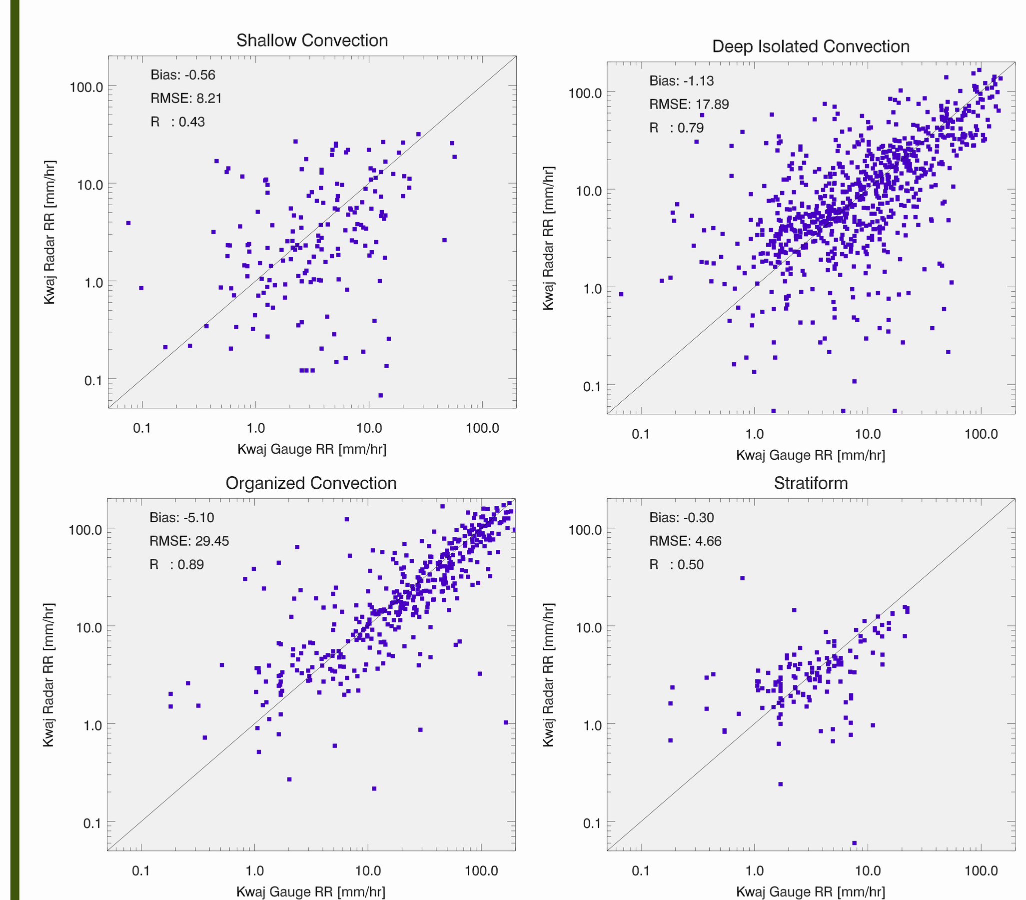


Regime Derived WPMM Z-R



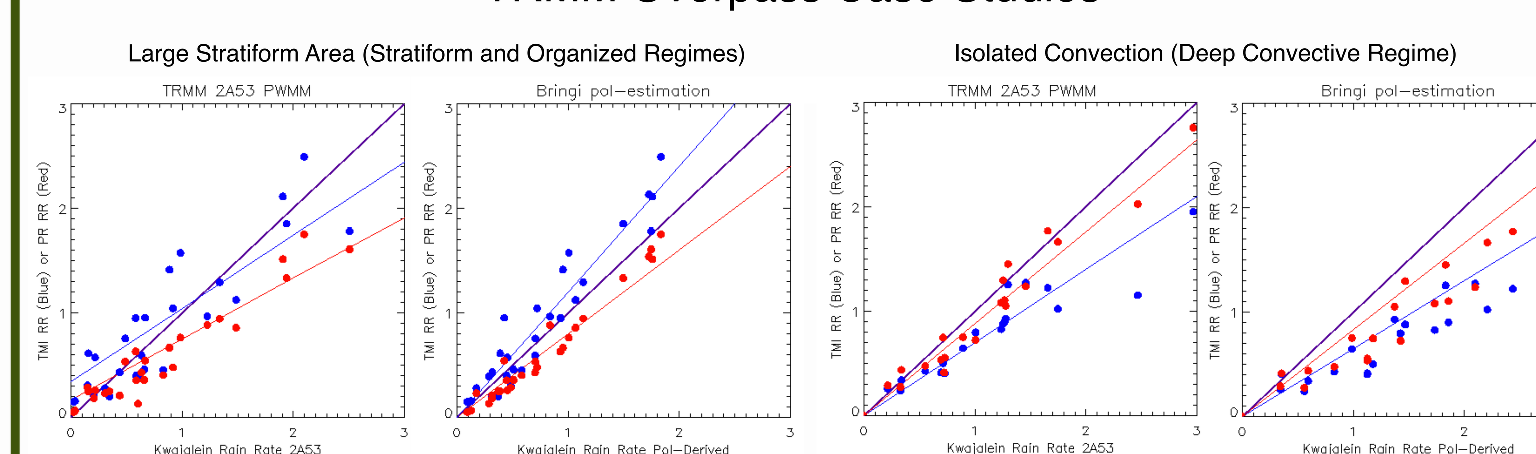
KPOL Dual-Polarized Estimates





- (Top) Density plots, created using the dual-pol derived rain rate and the 1.5 km CAPPI reflectivity, support the deviations found in the regime dependent WPMM results.
- (Left) Biases with gauges are also improved and scatter is reduced (RMSE) – many outliers do still exist. The use of polarimetric variables produces the most improvement in heavy rain rates where drops are larger and ice is more common.
- (Below) Pol-derived estimates are compared to TRMM overpasses in the 2011 and 2012 wet seasons. Cases chosen contain isolated convection or large stratiform anvils.
  - While underestimated, the PR retrievals best match isolated convection.
  - The correction to stratiform rainfall reveals that TMI may overestimate stratiform regions.

TRMM Overpass Case Studies



Summary

There are clear differences in Z-R relationships developed for the precipitation regimes and 2011 Kwajalein annually derived WPMM. The 2011 PWMM methodology overestimates stratiform and heavily underestimates intense convective rainfall for the deep and organized convection regimes.

- The regime dependent results greatly improve biases with ground gauges, however DSD variability still creates a large amount of scatter. Single Z-R relationships will always be subject to large amount of uncertainty.
- Polarimetric data combined with computed DSD parameters on a gate-by-gate instantaneous manner for rain rate computation yields better results with independent gauges than WPMM with dependent gauges.
- The the current Kwajalein WPMM Z-R relationship is not accurate enough to evaluate TRMM and GPM oceanic rainfall retrievals. The dual-polarized estimates capture the regime variability and currently provide the best rainfall estimates for satellite retrieved rainfall evaluation.

References

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