The Impact of Convective Regimes on Microwave Brightness Temperatures

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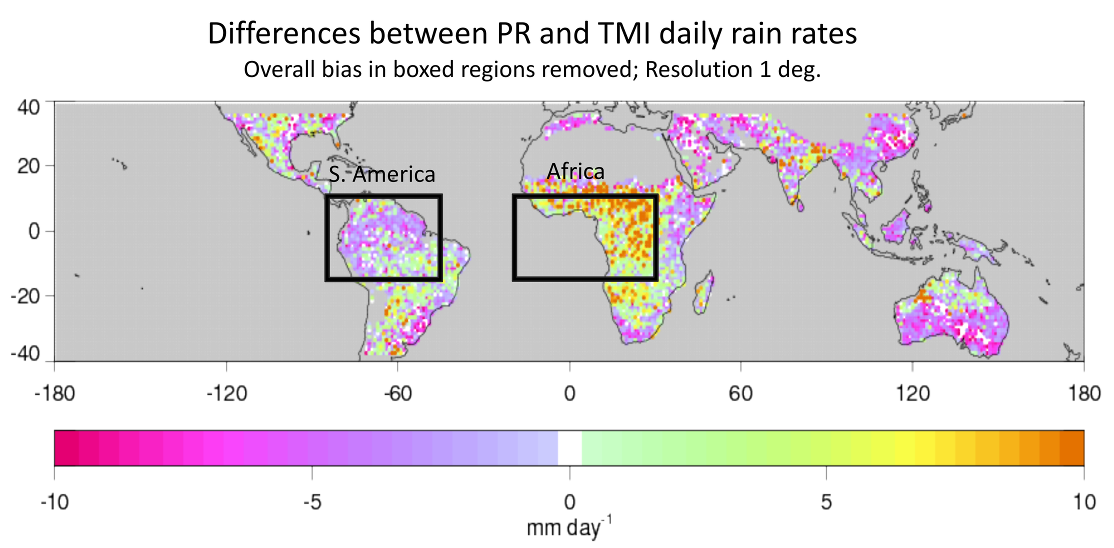
Objectives

The TRMM microwave rainfall retrieval over land was based strictly on the global-mean relationship between high frequency brightness temperature depression (ice-scattering) and rainfall rate. This leads to relative biases in regimes that, although similar, exhibit differences between the observed and assumed ice-to-rain ratio. To better understand what causes this variability we investigate links between a large-scale environment, microphysics, microwave brightness temperatures (Tbs) and organizational structure observed over the regions of similar surface type but opposite rain rate biases.

Regional Biases of GPROF Retrieval



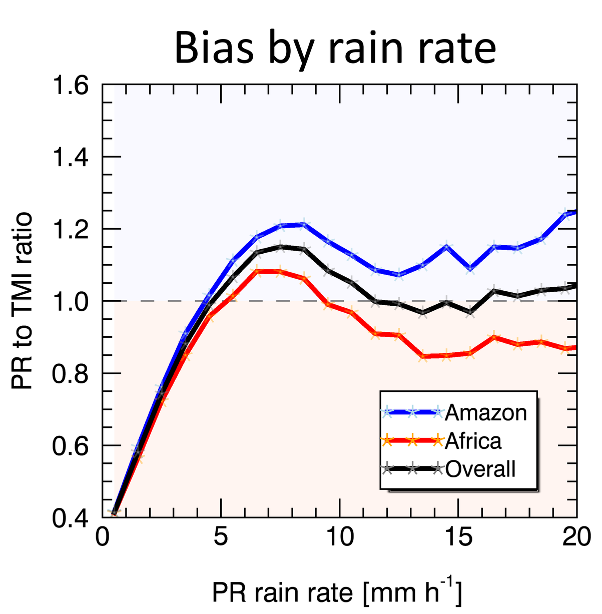


Figure 1. (above) reveals regions where GPROF retrieval (2010 version 2, *Kummerow et al. 2015*) underestimates (red-purple) and overestimates (green-orange) PR observations. The following analysis focuses on two boxed regions in South America and Africa to maximize differences in estimates by the two instruments while minimizing potential variability in surface type and climate regime (max vegetation and tropics). With the overall bias removed, the figure shows distinct opposites in the bias across all rain rates (left) over the Amazon and African regions.

Methodology and Data

We use one year of TRMM observations to locate regions dominated by persistent disagreement in TMI and PR rainfall estimates. Then, we use ECMWF reanalysis, PR reflectivity profiles and TMI brightness temperatures to search for links between the environmental conditions, Tbs and microphysical structure of precipitation regimes that can explain observed biases. Methodology from *Elsaesser et al. (2010)*, is adopted to separate 1° x 1° precipitating scenes into convective regimes based on their top echo height and stratiform-to-convective ratio.

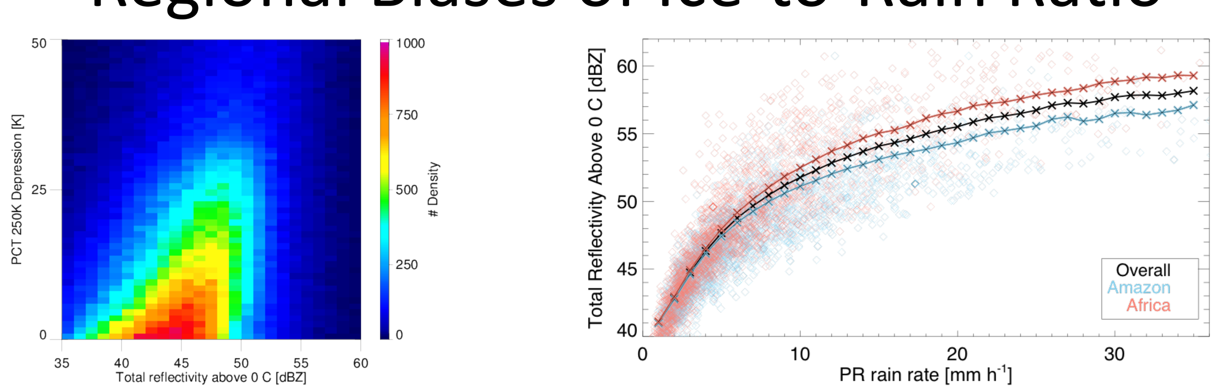
TRMM data products:

- TMI's brightness temperatures and rain rates
- PR's dBZ profiles, top echo height, precipitation type, and rain rates

ERA-Interim reanalysis (0.75° at 3- to 6-hour):

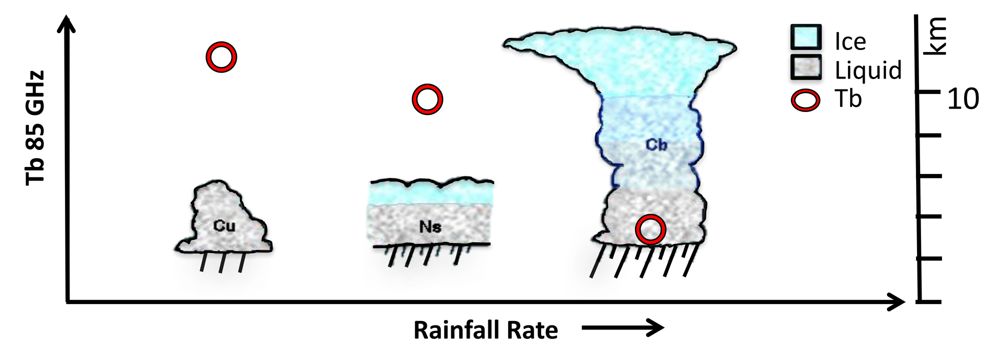
- Specific humidity profile, temperature, dew point, wind profile, and CAPE

Regional Biases of Ice-to-Rain Ratio



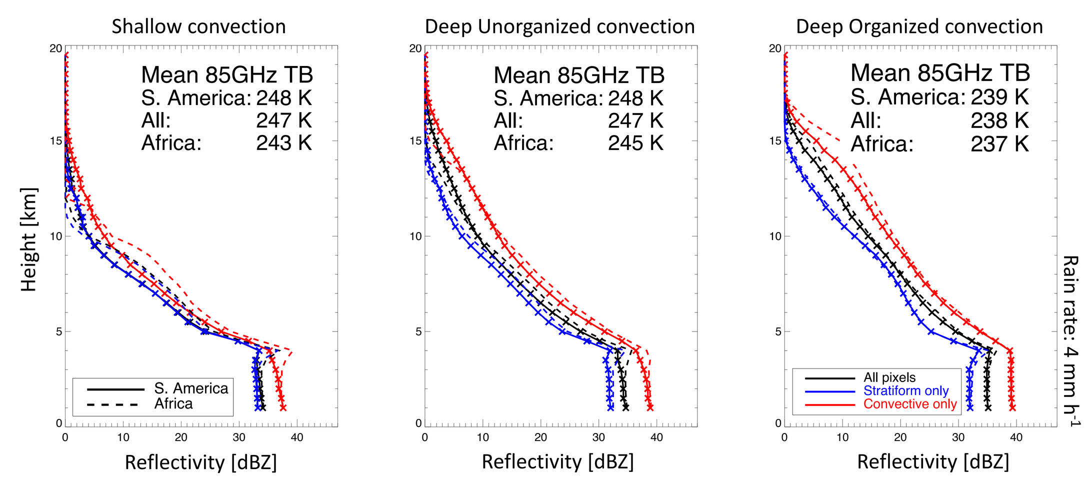
(left) Relationship between TMI and PR estimates of the ice amount in the cloud; (right) Relative comparison of the total amount of ice in the cloud column as a function of rain rate over the two regions. On average, African cloud systems show greater ice content across all rain rates.

Ice-to-Rain Ratio and Precipitation Regime



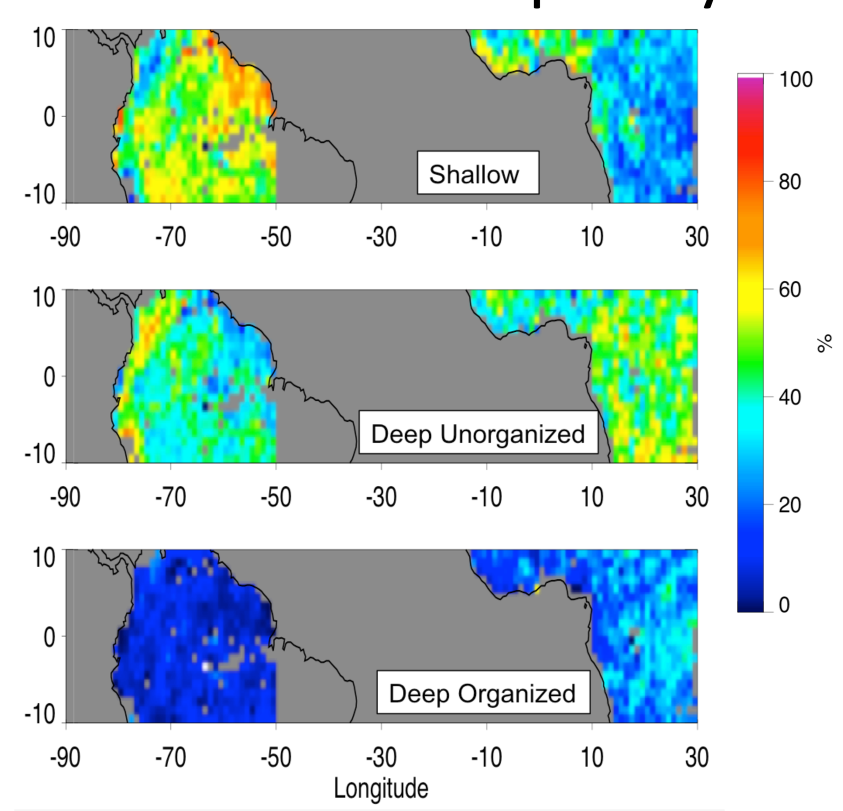
Deep organized precipitation regimes are expected to have higher ice-to-rain ratio than systems associated with shallow or unorganized convection. We use this argument to test how system organization relates to brightness temperatures and regional biases of the Amazon and Central Africa.

Precipitation Regimes



Using the methodology from *Elsaesser et al. (2010)*, one degree precipitating scenes over the Amazon and Central Africa region are separated into: *shallow, deep-unorganized,* and *deep-organized* regimes. Reflectivity profiles for low rain rate (4 mm h^{-1}) sampled by precipitation regime is shown above together with 85 GHz brightness temperature variability.

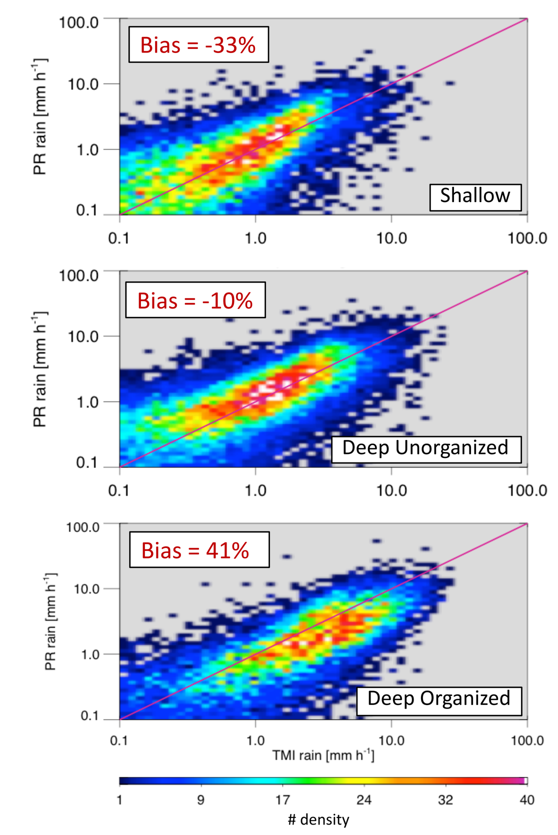
Relative Frequency of Occurrence and Regime Related Bias



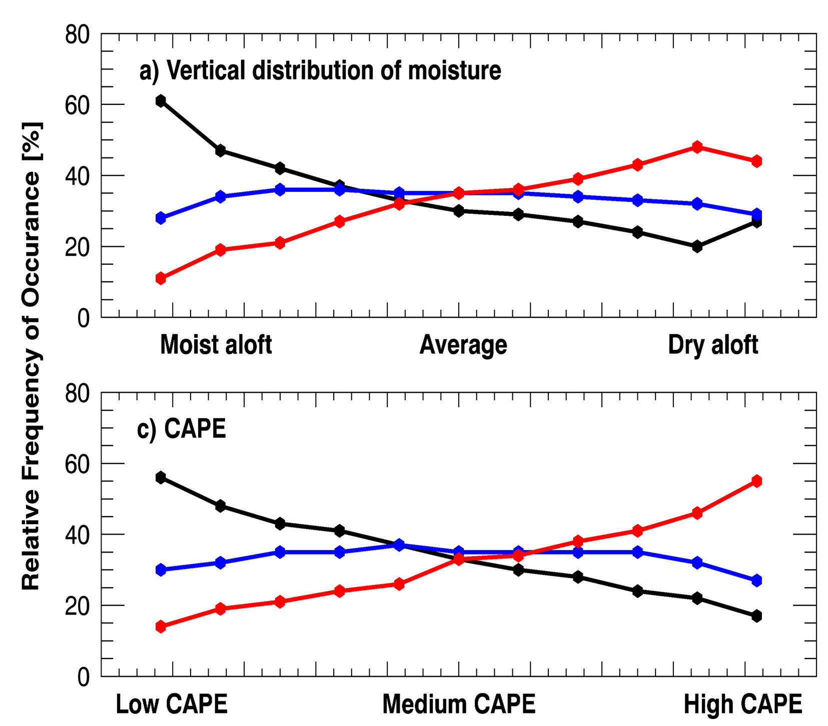
Map of the relative frequency of occurrence of the three regimes depicts the preference of the Amazon region for shallow regime. On the other side, deep organized regime is more common to the African region (left).

Shallow regime dominates both frequency and total rainfall over the Amazon, while deep organized regime, accounts for up to 60% of the total rainfall (not shown here) with relative occurrence of only 15-30%.

Compared against PR measurements, TMI rain estimates show distinct bias between the shallow and deep organized regimes (right), implying the source of PR-to-TMI regional differences seen in Figure 1.

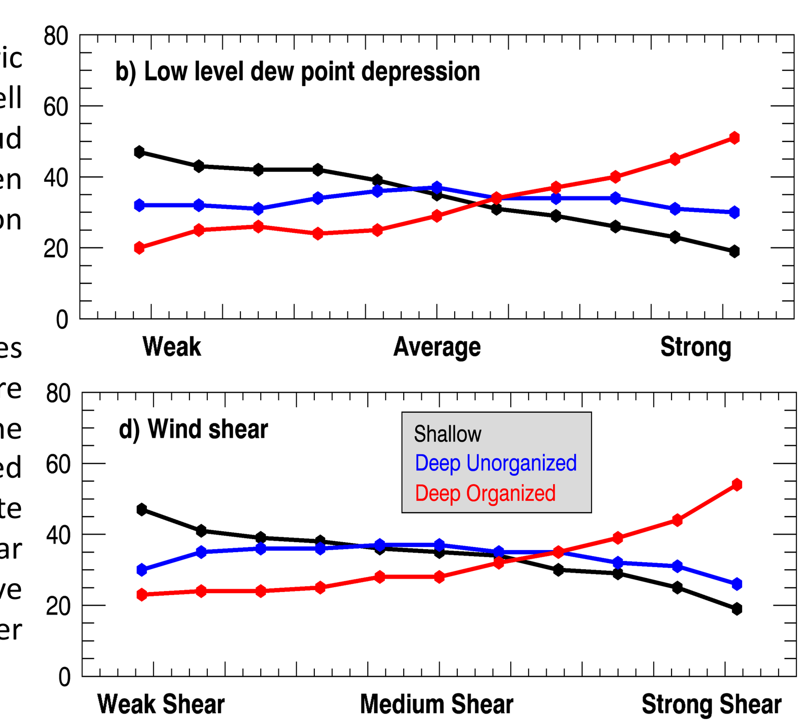


Links Between the Environment and Precipitation Regime



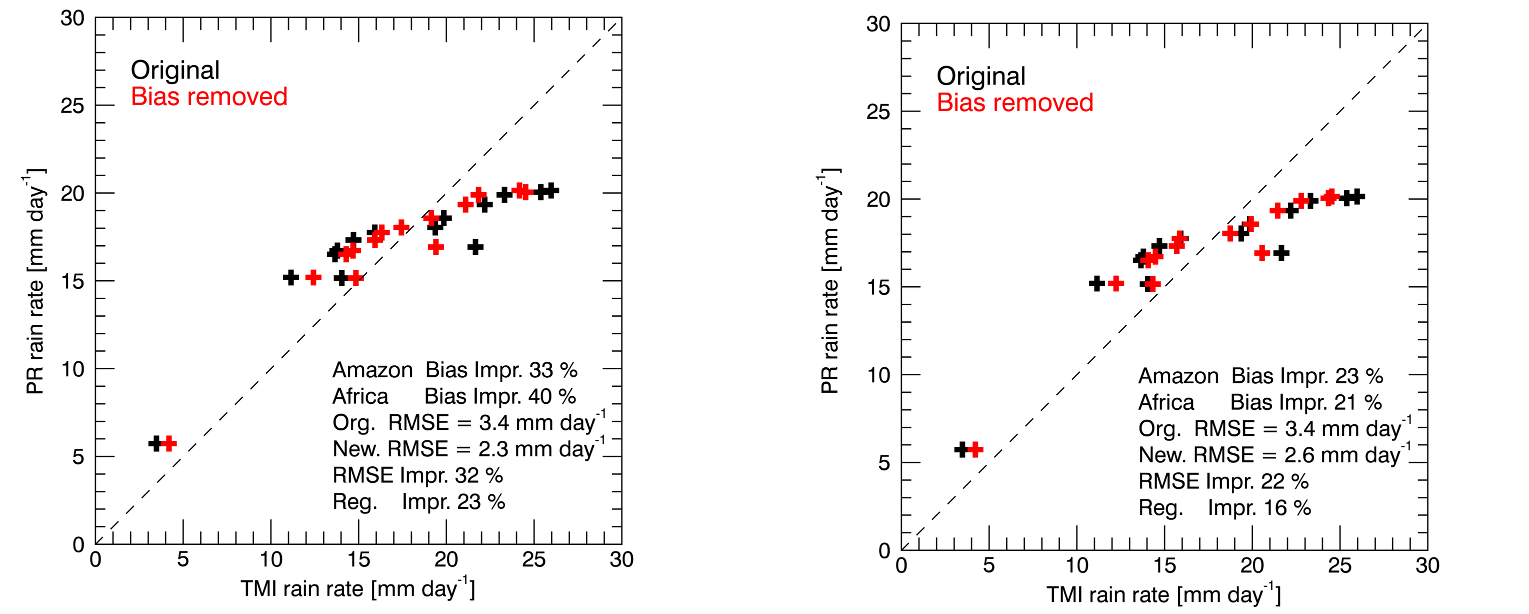
Sampling the atmospheric conditions by criteria that are well known to play a key role in cloud formation reveals the links between the environment and precipitation regimes.

Strong shear, high CAPE values and dry aloft conditions are preferably seen prior to the formation of deep intense organized systems. Shallow regimes dominate in low CAPE and weak shear environments with higher relative humidity values in the lower atmosphere.



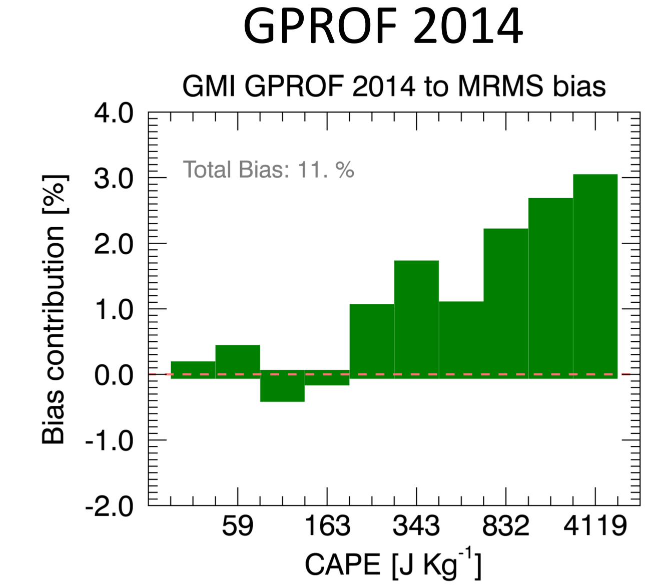
Applications

GPROF 2010

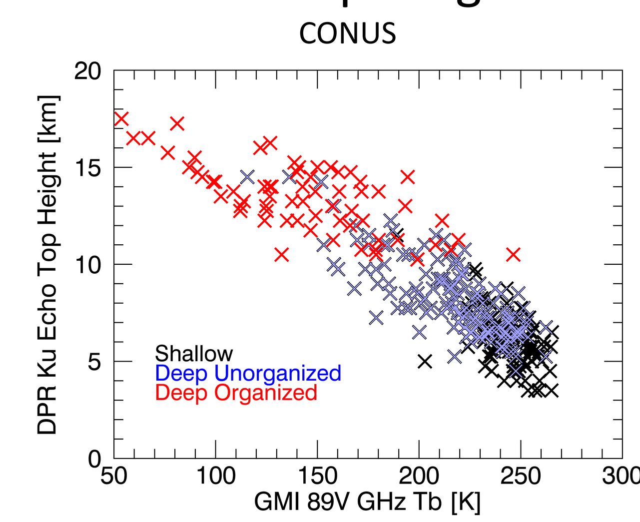


A combination of CAPE and wind shear (left) and humidity distribution (right) is used to predict and then remove the TMI bias in GPROF 2010 algorithm over the regions shown in the Figure 1. The results show up to 30% of RMSE and up to 40% in bias reduction between TMI and PR at 10° x 10° grid.

GPROF 2014



Echo Top Height



Using the same approach, a large-scale environment relation to the bias between MRMS and GPROF2014 GMI rain rate over the CONUS is assessed (left). Majority of GMI overall overestimate (11%) comes from events characterized by high CAPE values.
Strong correlation between GMI's 89 GHz Tbs and both precipitating system top height and precipitation regime is seen as a potential in some aspects of NWP validation.

Conclusions

The impact of convective regimes on microwave brightness temperatures is investigated by looking into the causes of differences in the microphysics of precipitating systems in Amazon and Central Africa regions. Findings could offer a key for eliminating systematic errors seen in passive satellite rainfall measurements.

- Large-scale biases between TMI and PR observations are linked to storms' Tb signatures, microphysical and organizational structure:
  - Distinct differences are found in vertical profiles of three structurally different precipitation regimes: shallow, deep unorganized, and deep organized convection
  - A strong consistency in bias contribution and radiometric properties is found over the Amazon and Central Africa regions for each of the three regimes
- Precipitation regimes are linked to environmental conditions observed prior to the development of precipitating systems
  - High CAPE and strong wind shear with dry air aloft are found to be preferable conditions for development of deep-organized systems (characterized by positive GPROF bias)
  - Shallow systems (characterized by negative GPROF bias) are preceded by low CAPE and weak shear values with higher relative humidity in the lower atmosphere
  - All high frequency Tbs, the vertical structure and ice-scattering signal of precipitating scenes show strong and consistent dependence on changes in environmental conditions
- Up to 35% of satellite large scale regional biases can be removed by using the environment to predict a precipitation regime and differences between the actual and mean global ice-to-rain ratio.

References and Acknowledgments

[1] Kummerow, C. D. et al. 2015: The Evolution of the Goddard Profiling Algorithm to a Fully Parametric Scheme. *J. Atmos. Oceanic Technol.*, 32, 2265–2280.
[2] Elsaesser, G. S. and coauthors, 2010: Observed Self- Similarity of Precipitation Regimes Over the Tropical Oceans. J. Climate, 23, 2686 – 2698.

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