

Investigating Differences in Rainfall Distributions from a Constellation of Sensors

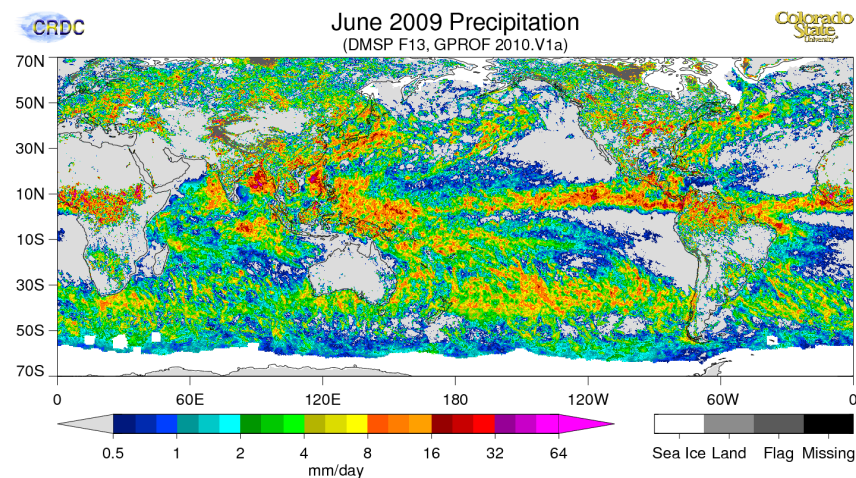
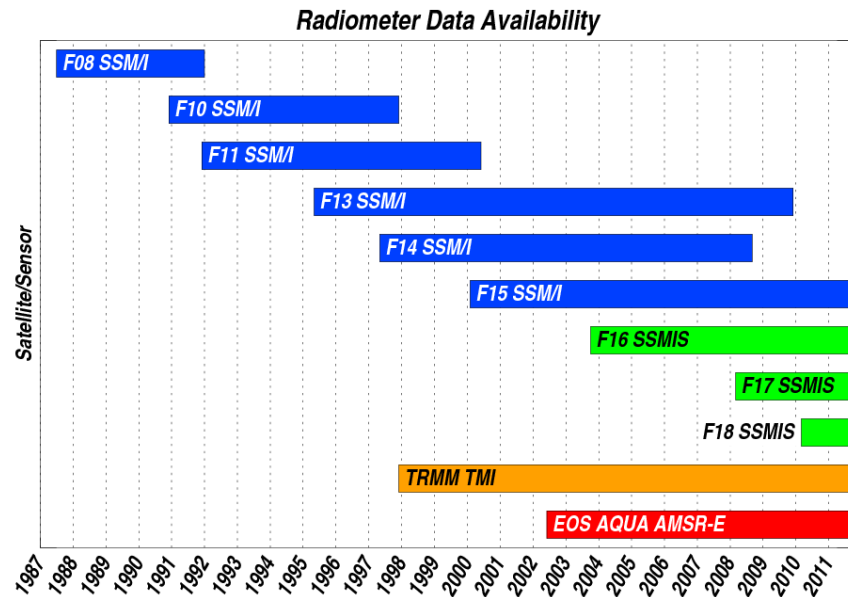
with results from
TRMM Version 7, SSM/I, and CloudSat

Wesley Berg

*Dept. of Atmospheric Science
Colorado State University*

GPROF 2010 Rainfall Products

Application to a Radiometer Constellation



Radiometer Constellation

Current

- SSM/I on board F08, F10, F11, F13, F14, and F15
- TRMM TMI (2A12 V7)
- EOS AQUA AMSR-E

Coming soon!

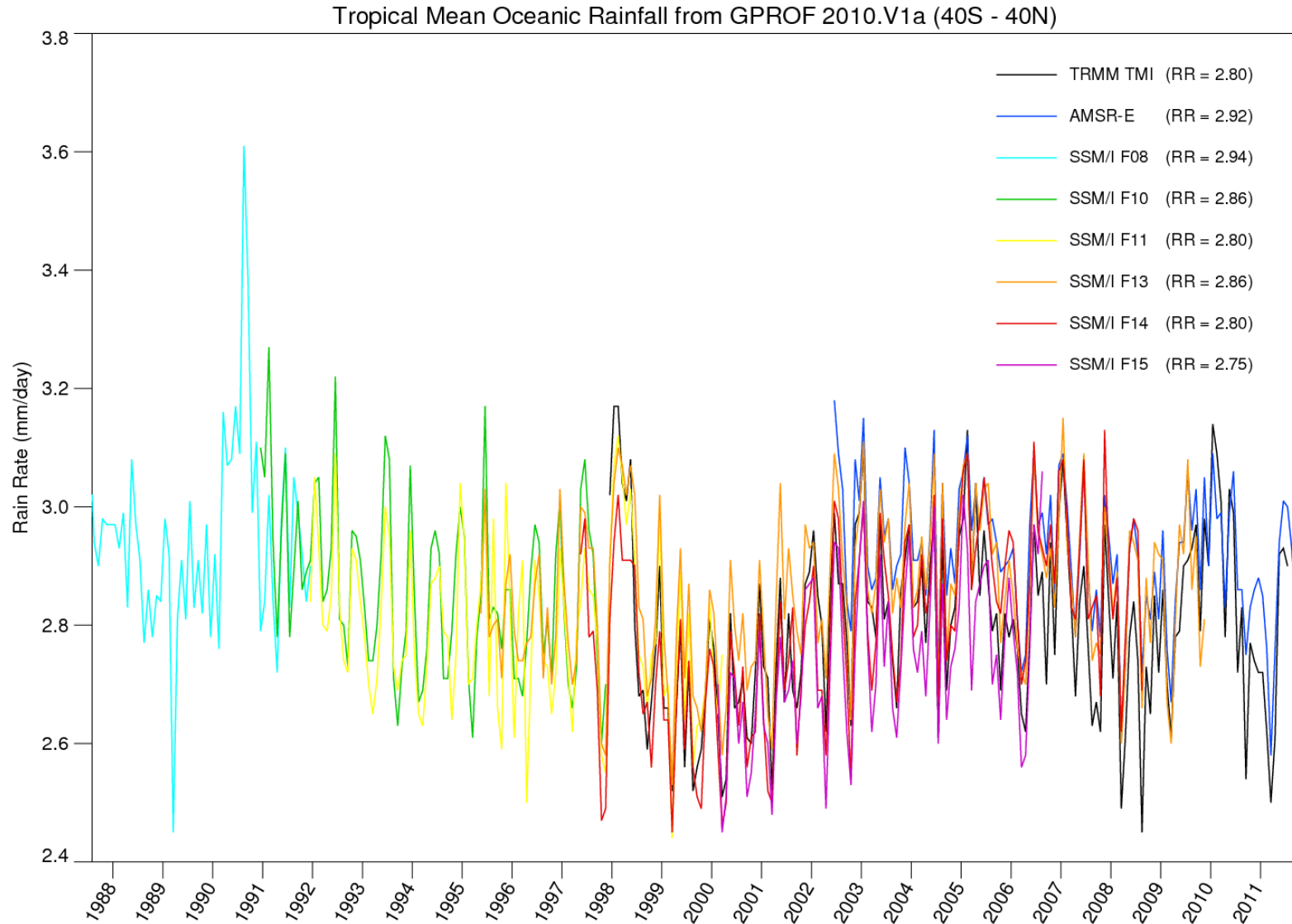
- SSMIS on board F16, F17, and F18

Future

- Megha Tropiques
- GCOM-W1
- GMI
- SSMIS on board F19, F20
- WindSat?
- FY3?
- Russian?

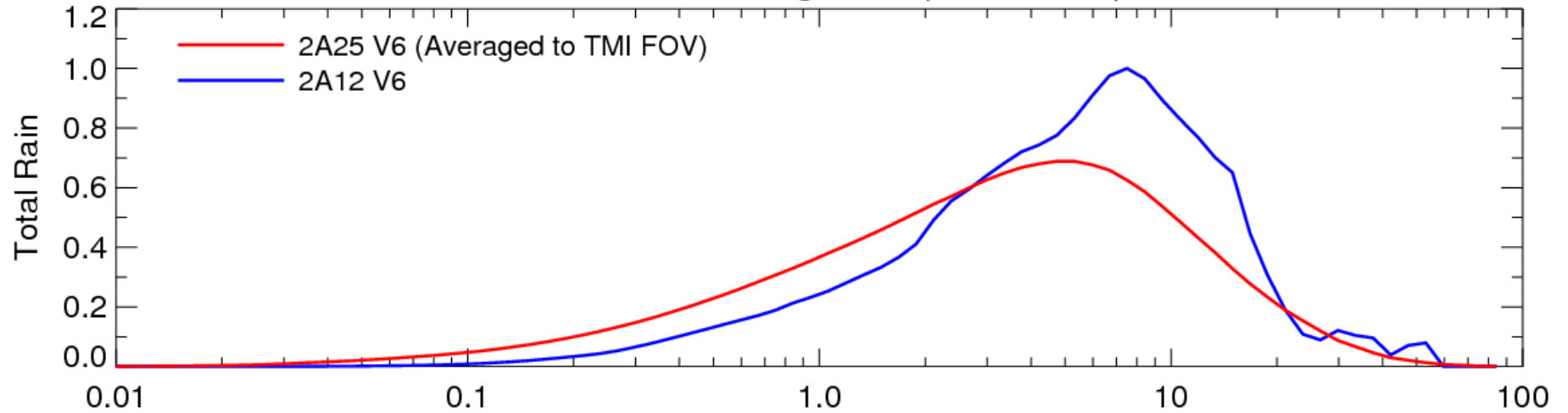
Developing and analyzing long-term rainfall data records is highly complementary with developing consistent retrievals from the GPM constellation.

GPROF 2010 Rainfall Time Series

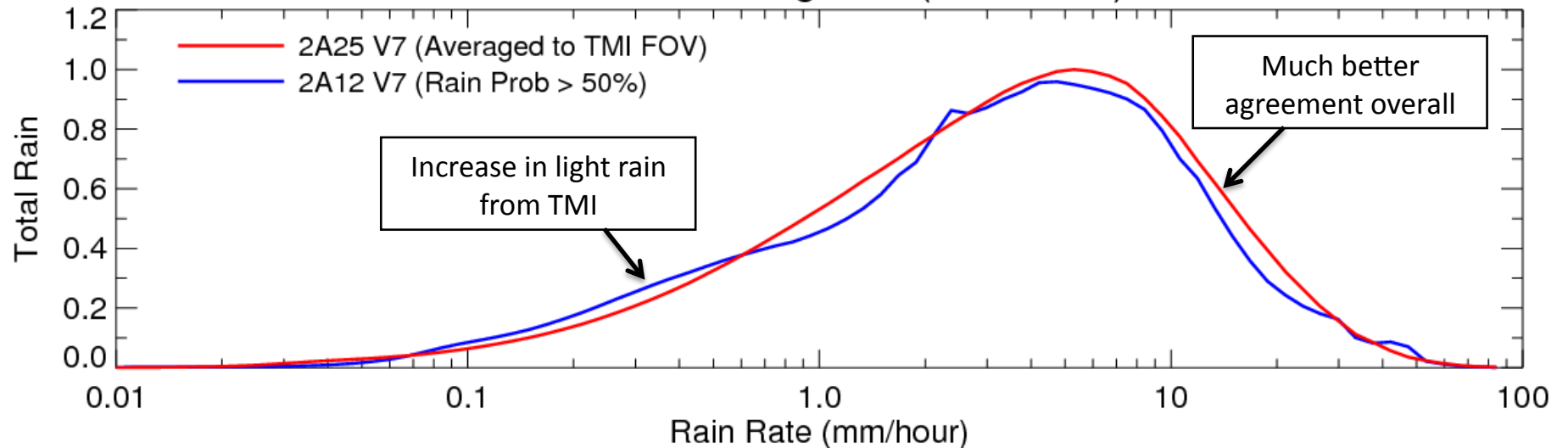


Rain Rate Distributions

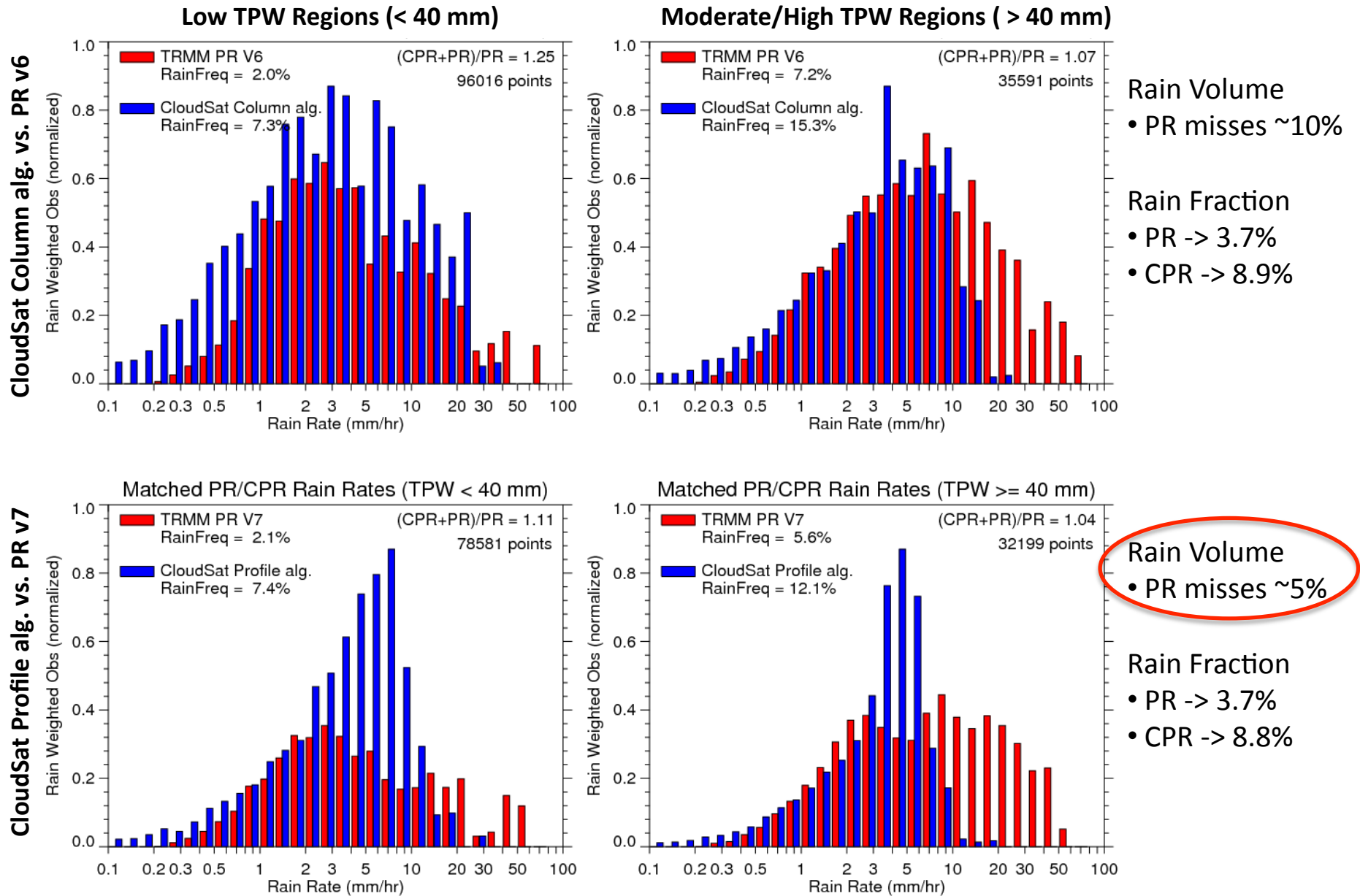
Rain Rate Histograms (TRMM V6)



Rain Rate Histograms (TRMM V7)

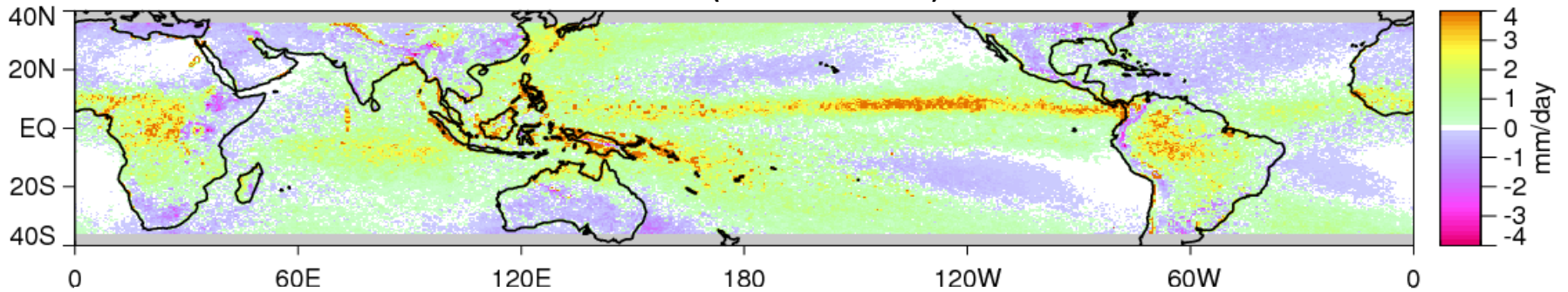


Colocated PR and CloudSat Rain Rate Distributions

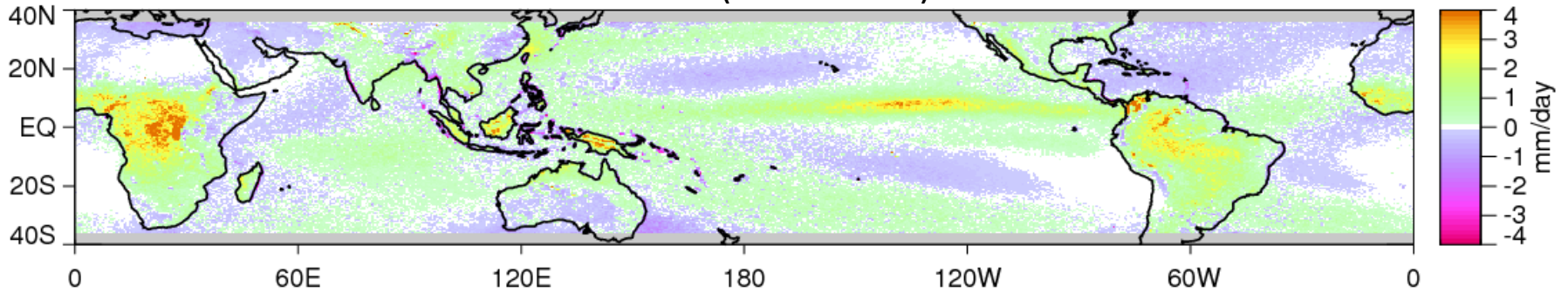


Regional TMI – PR Differences

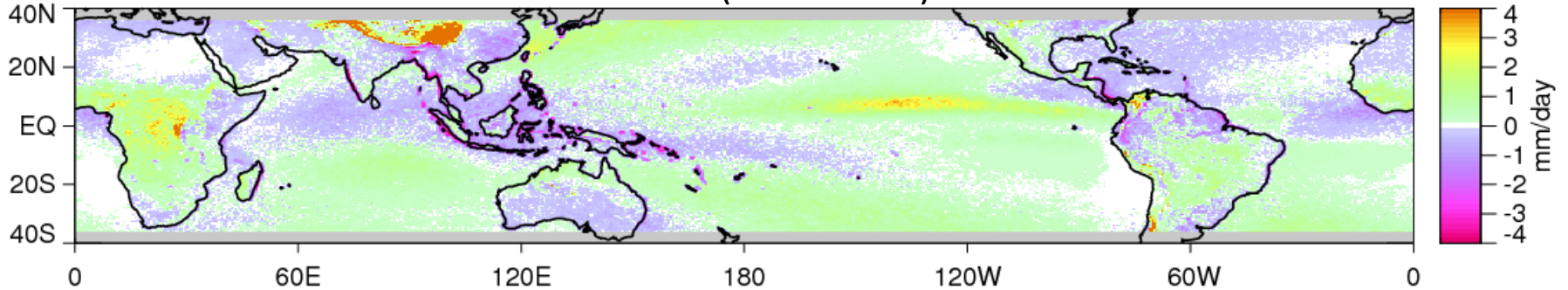
Version 5 (Mean = 23%)



Version 6 (Mean = 9%)

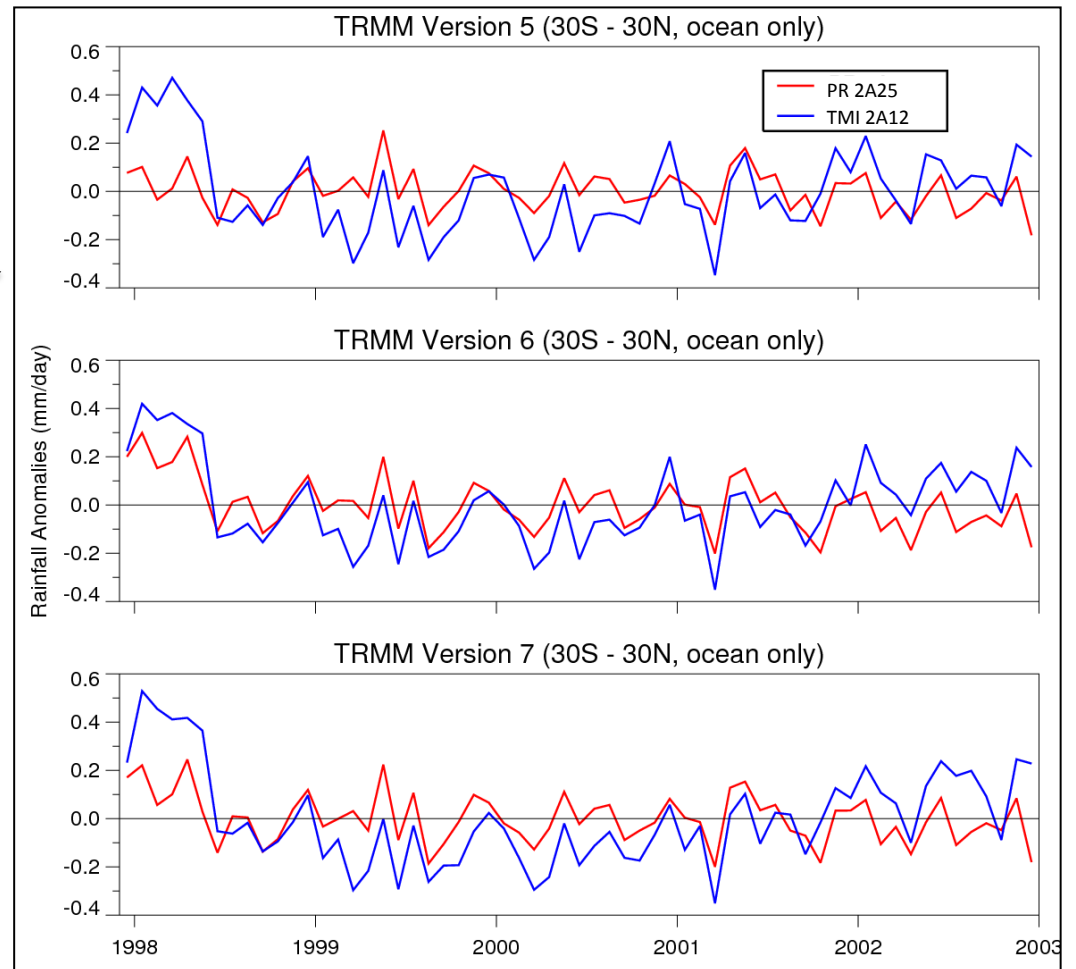
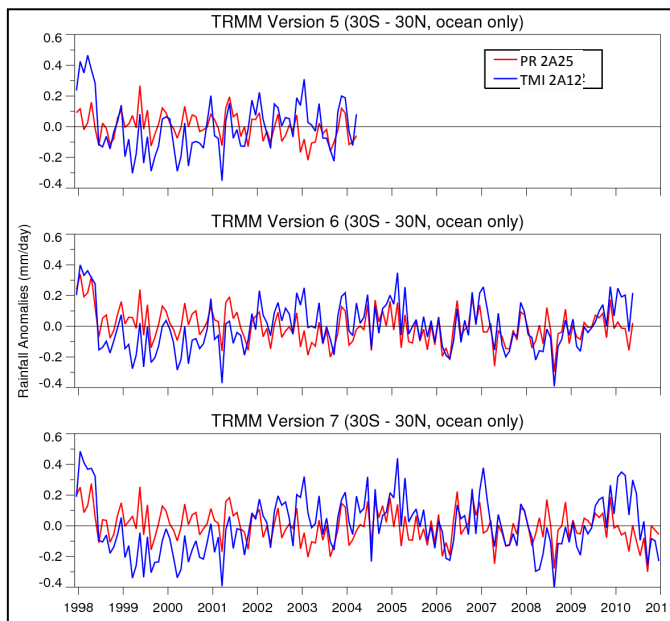


Version 7 (Mean = 6%)



Time Series of TRMM Precipitation Anomalies

Tropical Mean Oceans (30S to 30N)



- V5 PR time series shows no increase in rain associated with 97/98 ENSO
- V6 PR shows ENSO increase
- V7 PR ENSO increase is less than V6
- Small change in interannual variability of TMI rainfall between versions
- PR rainfall anomalies relatively flat over time while TMI anomalies show significant interannual variability

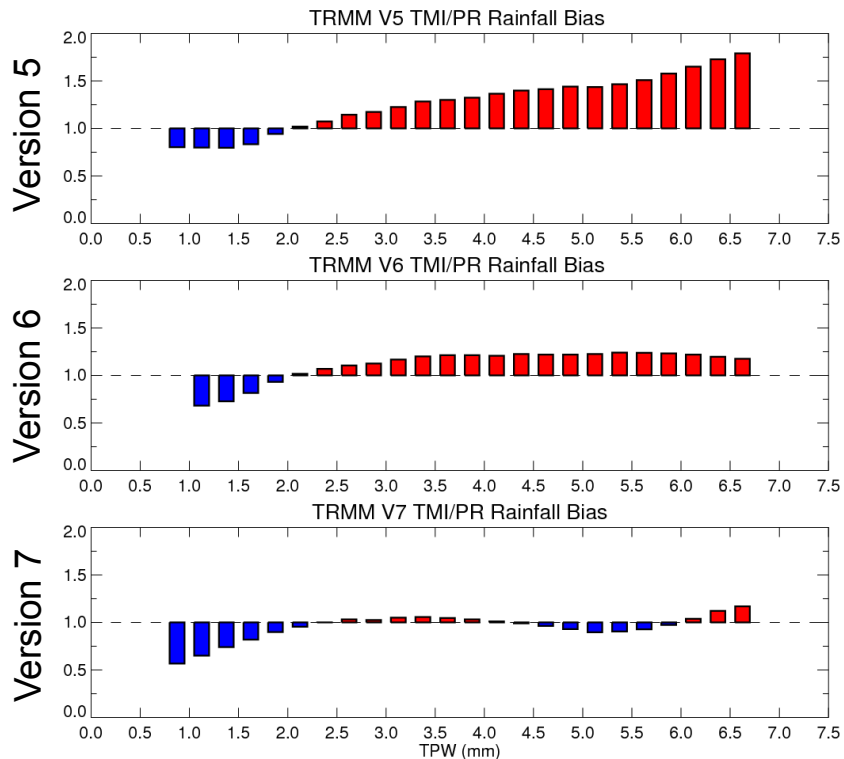
Fundamentals of the Bayesian Retrieval

Definitions and Important Concepts

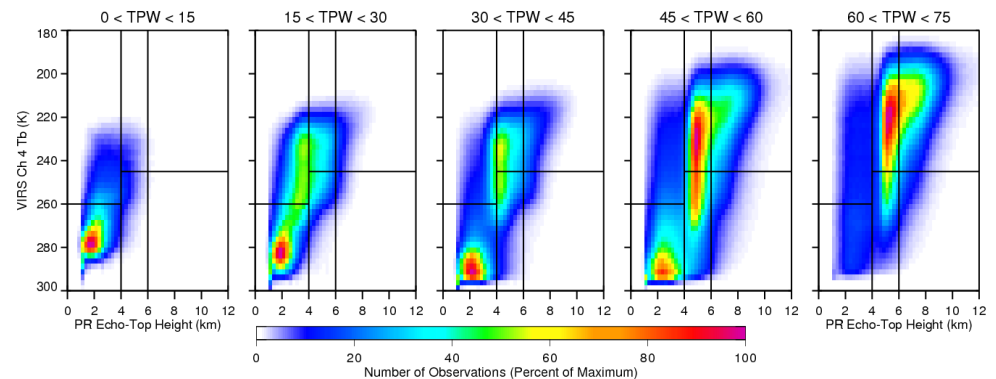
- The radiometer retrieval is fundamentally underconstrained given only 9 brightness temperatures for TMI (7 for SSM/I), which are not all independent. This means that pixels with similar T_b can have different structure and other characteristics.
- To deal with this GPROF uses an a priori database containing rain rates and profile information along with T_b . This database was constructed using matched TMI and PR information along with hydrometer profiles from CRM simulations.
- The Bayesian approach utilized by GPROF averages a number of profiles from the database with similar T_b . As a result, profiles from very different rain systems can get averaged together.
- The a priori database is stratified by SST and TPW to distinguish between raining profiles with similar T_b , but from different regimes.
- The **v7 database** modifies the hydrometeor profile in a bulk statistical sense to better match both the PR reflectivity profile and TMI T_b . This results in changes in the surface rain rates from the original 2A25 estimates in the final v7 database.
- The **empirical database** uses unmodified 2A25 rain rate estimates with collocated TMI T_b .

Rainfall and Cloud Characteristics as a Function of TPW

TMI/PR Rainfall Biases vs. TPW



2D Histograms as a Function of Total TPW

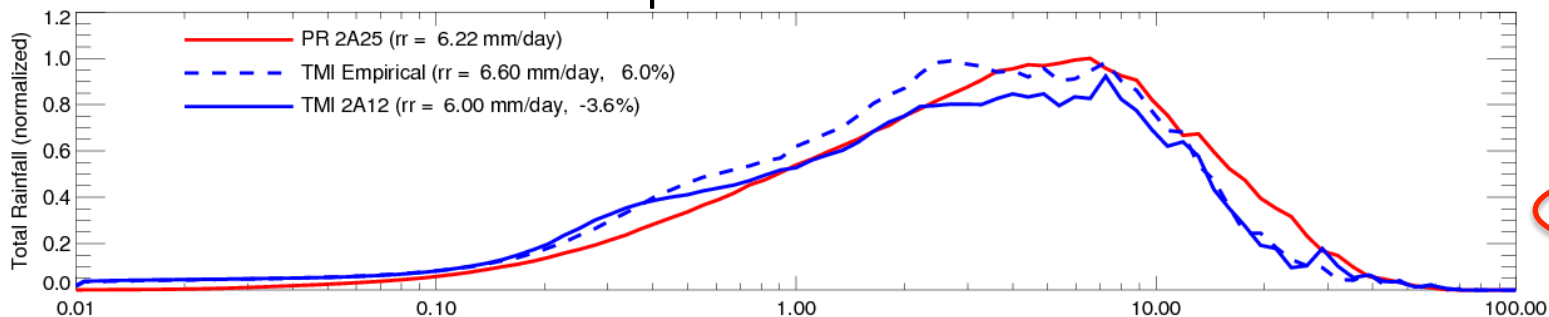


- V5 products showed a strong correlation between TPW and TMI-PR rainfall biases
- TPW is a good proxy variable for freezing height, which is important to relate the column liquid observed by TMI to a surface rain rate
- The structure of rain systems changes significantly with TPW.
- Solution was to stratify TMI a priori database by SST and TPW (v5/v6 stratified only by SST).

Regional Rain Rate Distributions

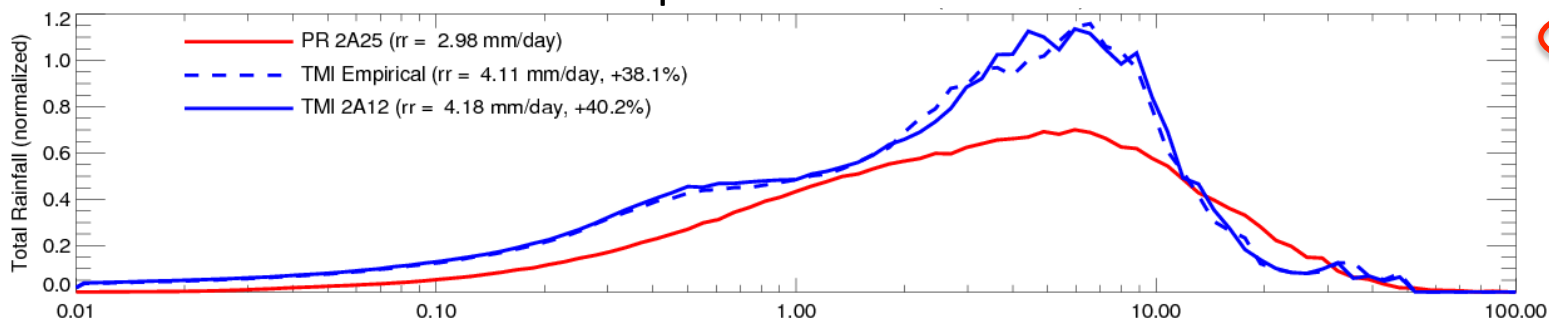
TMI vs. PR

Tropical West Pacific



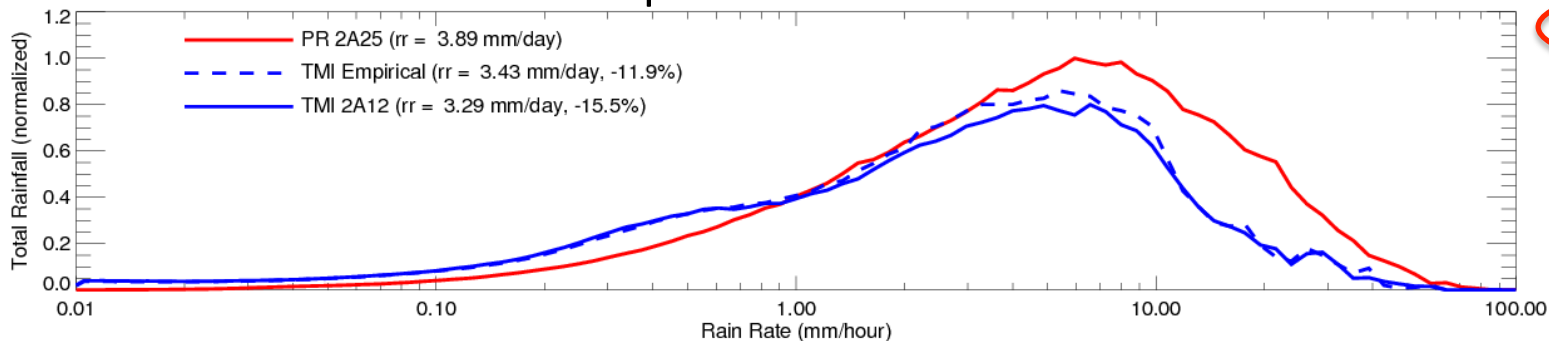
TMI V7 4% low
 TMI Emp 6% high
 Emp > V7 ~10%

Tropical East Pacific



TMI V7 40% high
 TMI Emp 38% high
 Emp < V7 ~2%

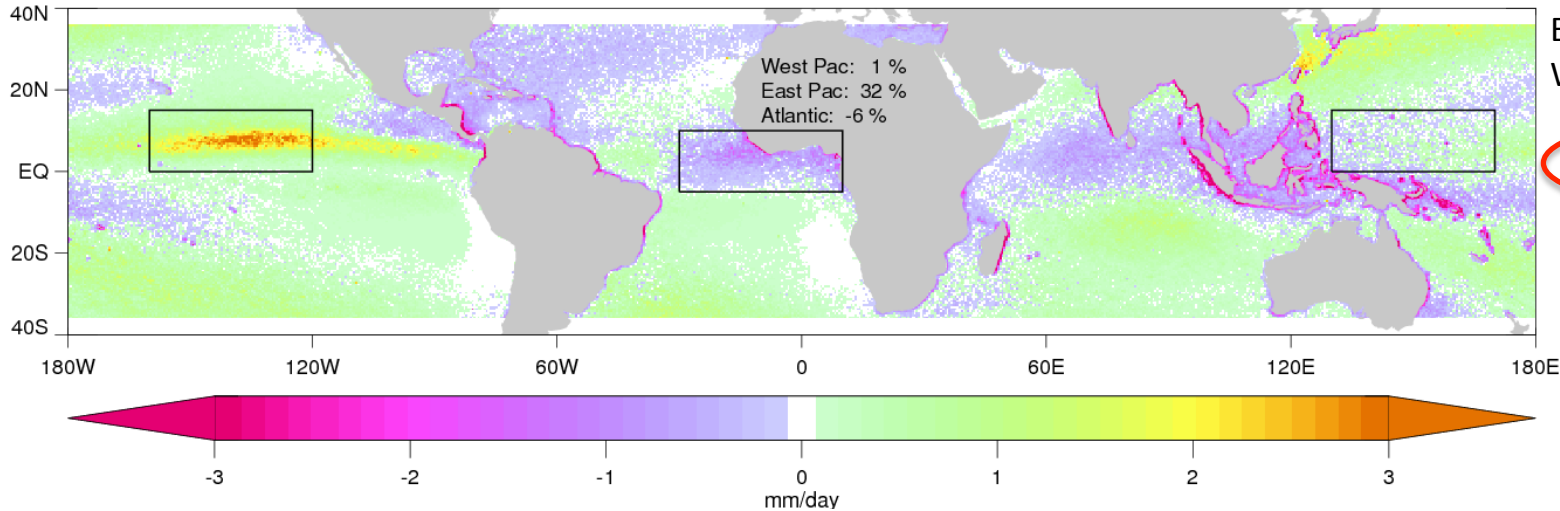
Tropical East Atlantic



TMI V7 16% low
 TMI Emp 12% low
 Emp > V7 ~4%

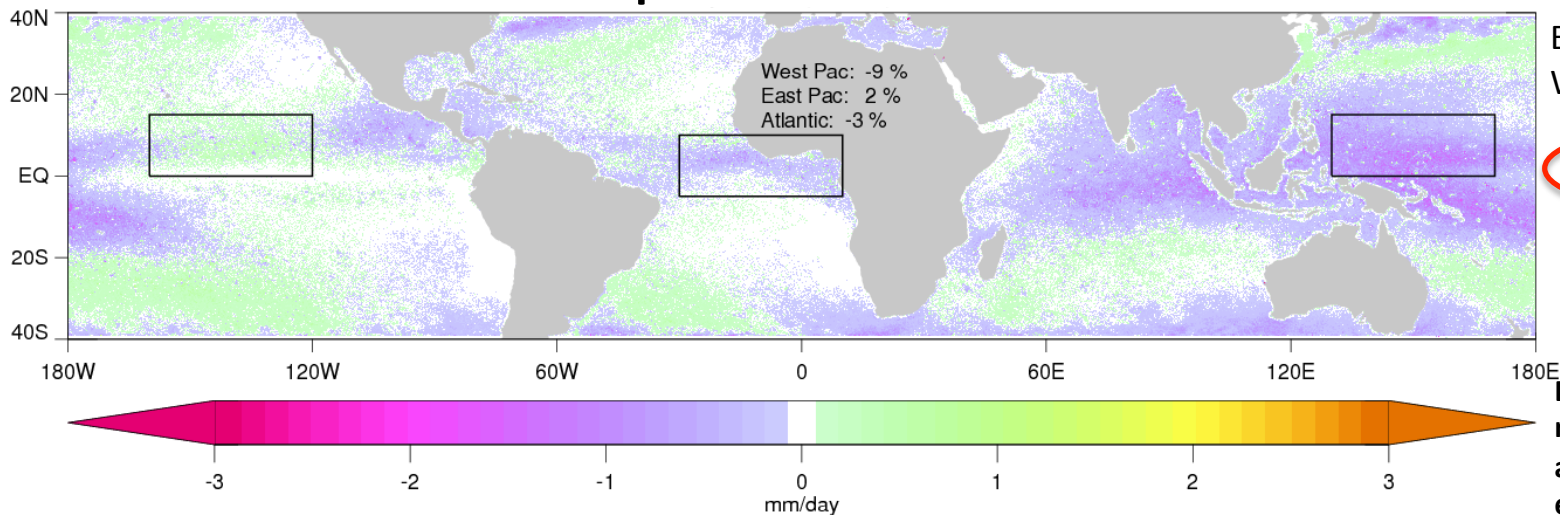
TMI – PR Rainfall Biases as a Function of Region

TMI V7 Retrieval – PR V7



East Pac: 32% > PR
West Pac: 1% > PR
Difference: 31%

TMI Empirical Retrieval – PR V7



East Pac: 2% > PR
West Pac: 9% < PR
Difference: 11%

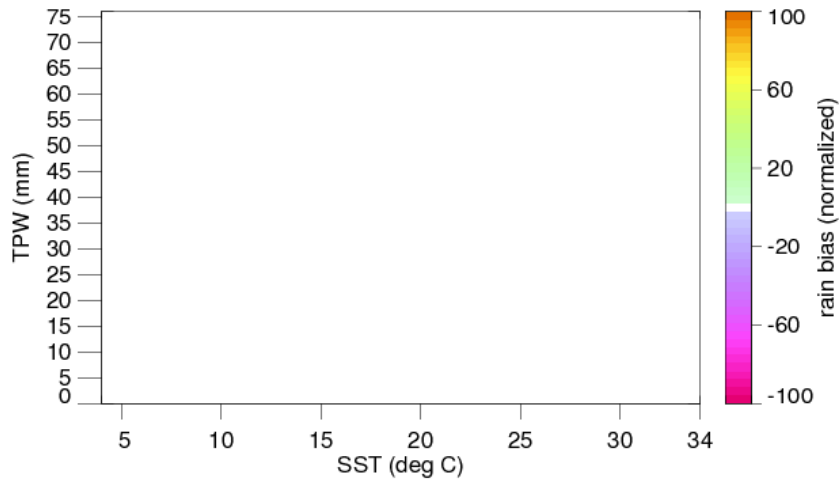
Differences suggest regional changes in DSD are a factor, but don't explain the entire bias

TMI – PR Rainfall Biases

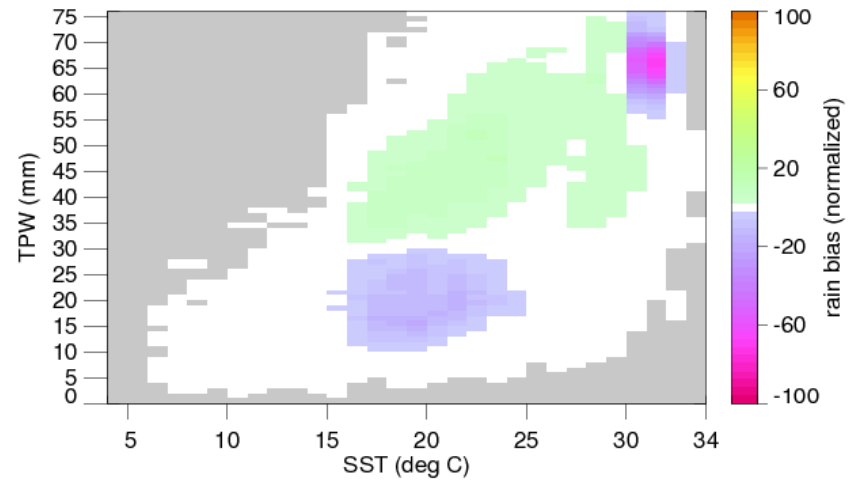
as a Function of SST and TPW

Database

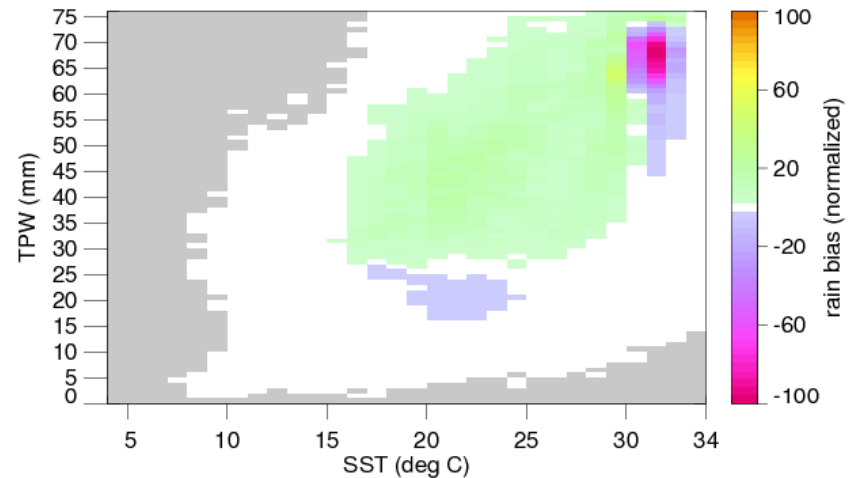
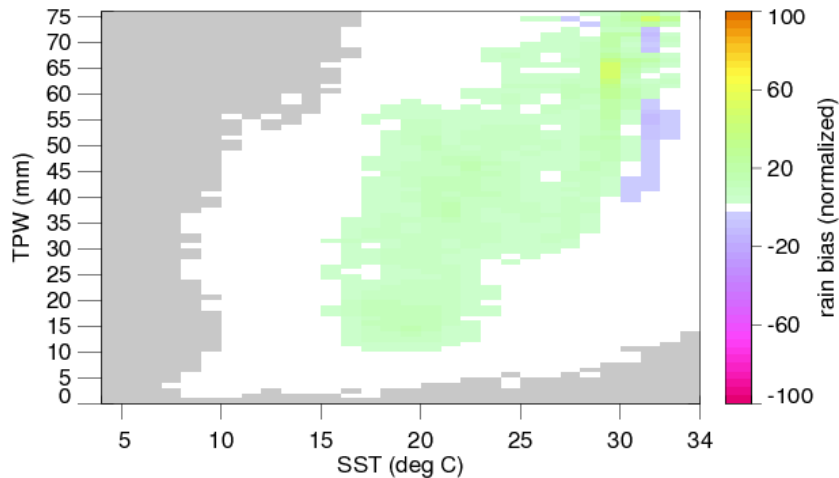
TMI Empirical - PR



TMI Version 7 - PR

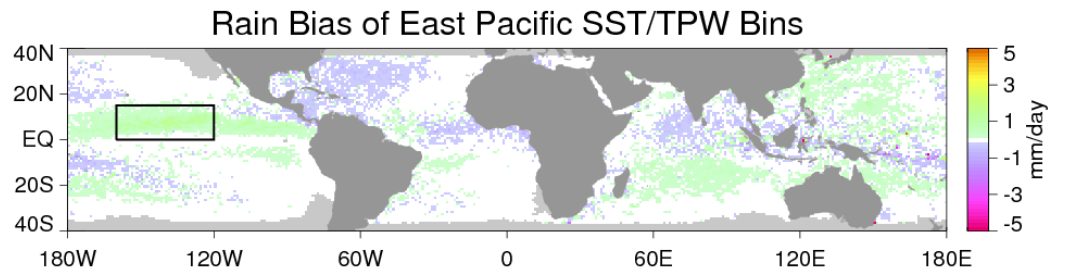
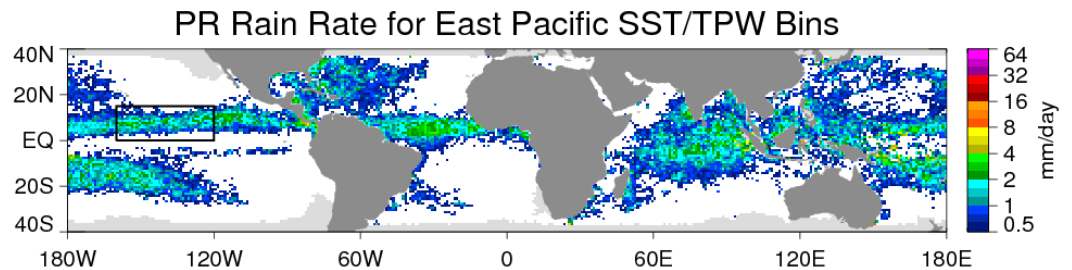
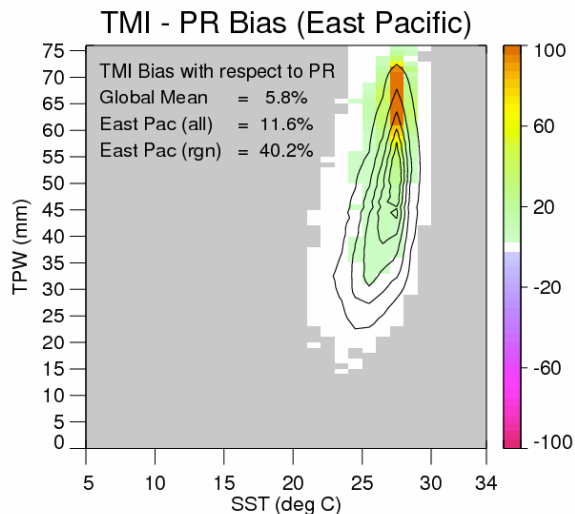
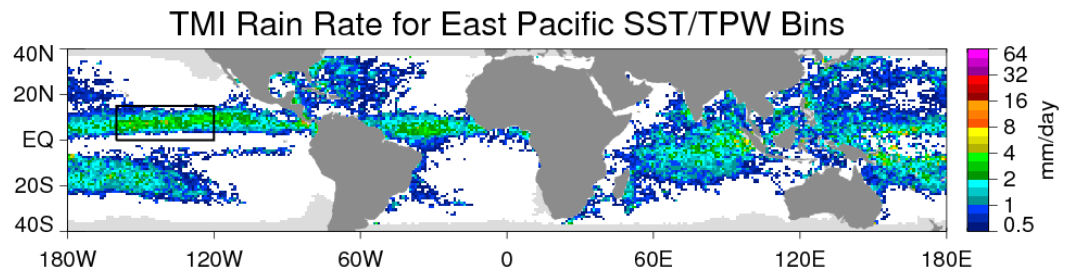
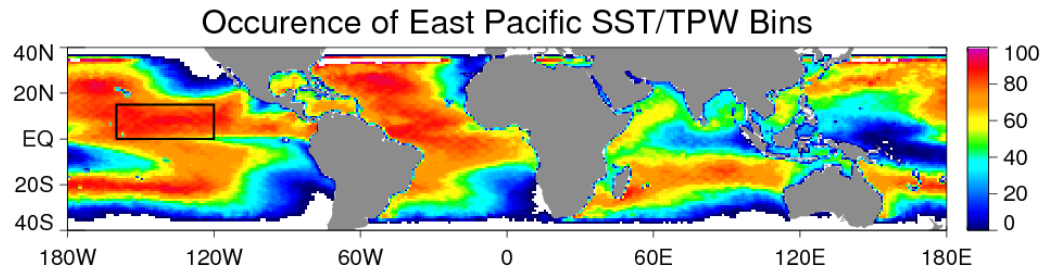
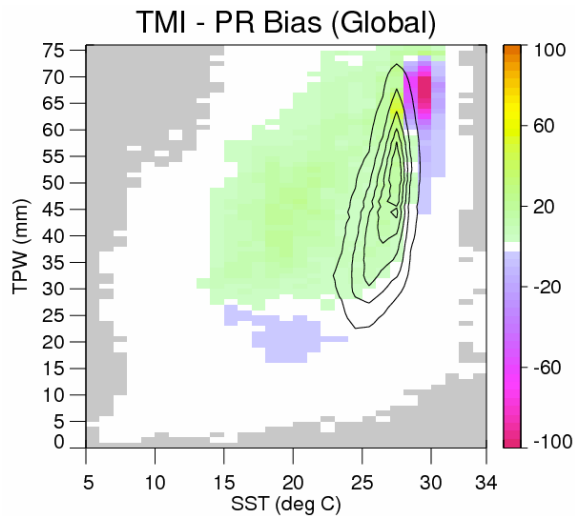


GPROF Retrieval



Impact of Database Averaging

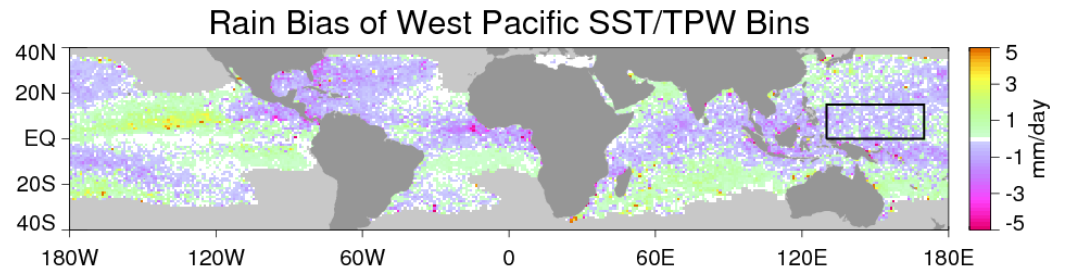
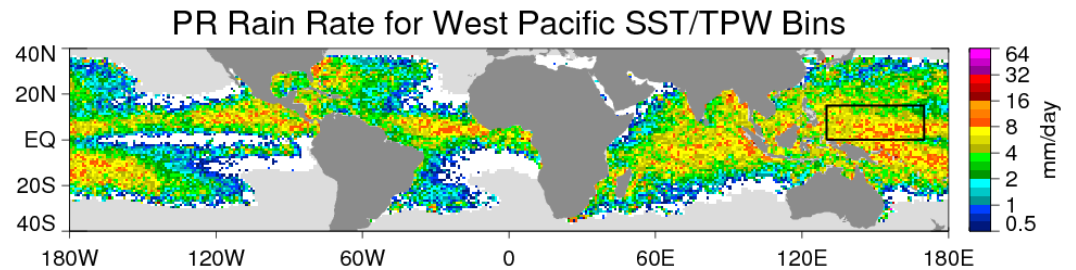
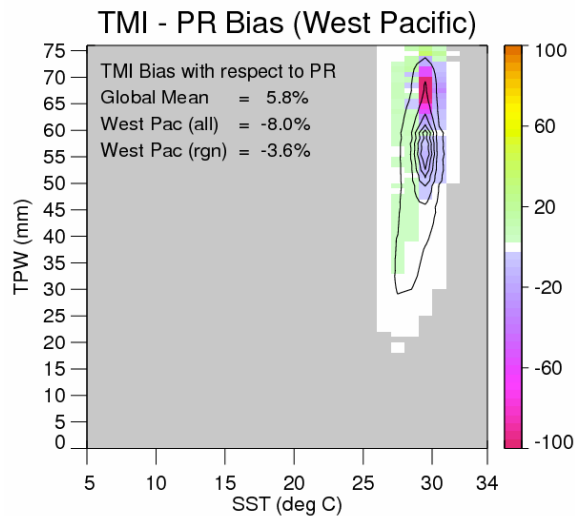
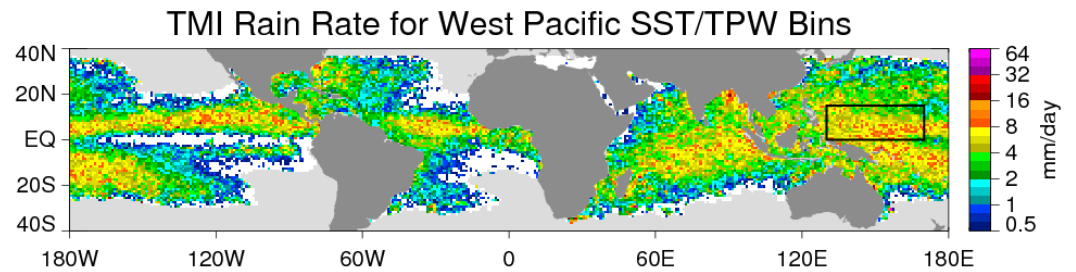
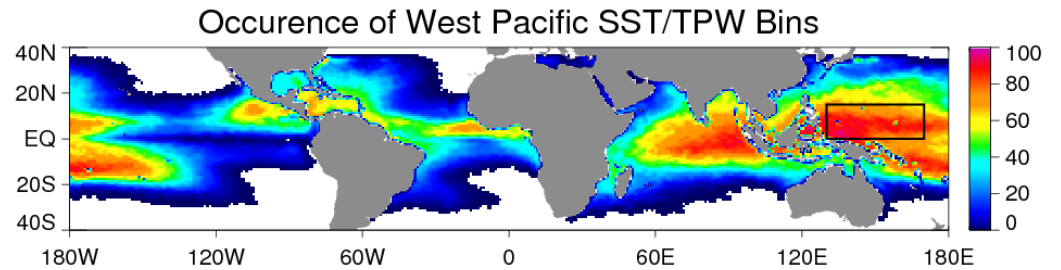
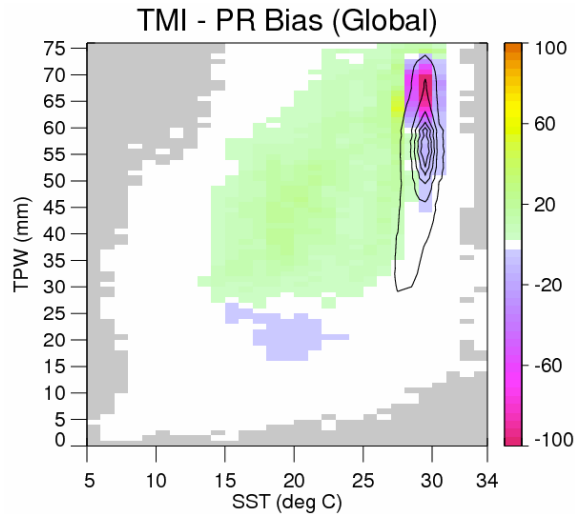
Tropical East Pacific



Mean SST = 26.6 degrees
 Mean TPW = 45 mm

Impact of Database Averaging

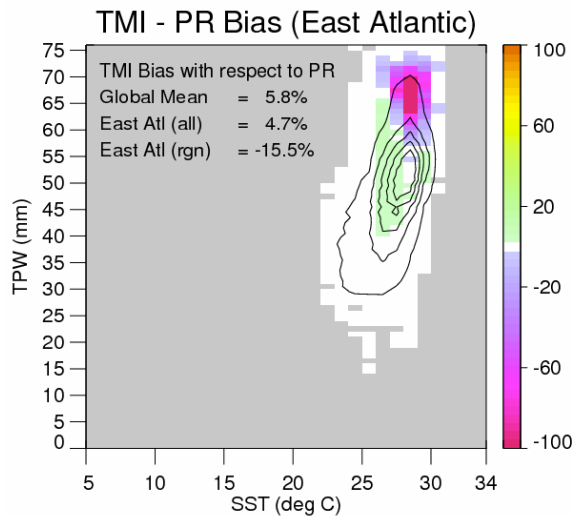
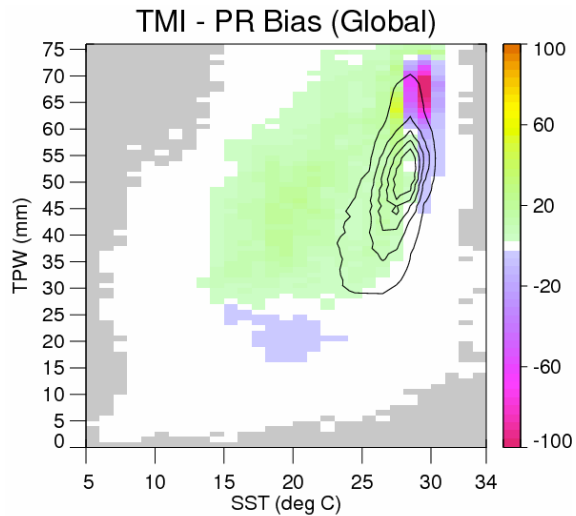
Tropical West Pacific



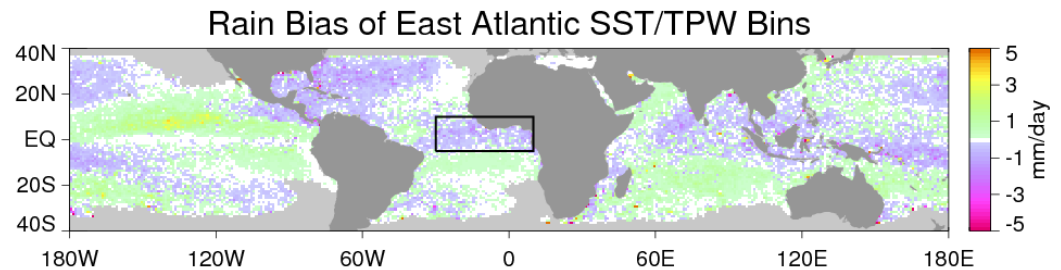
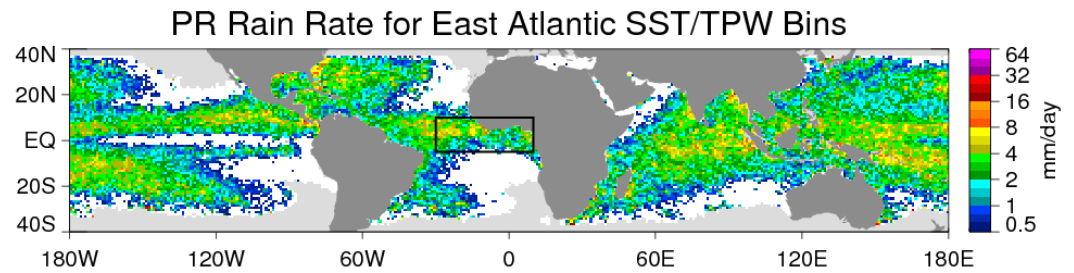
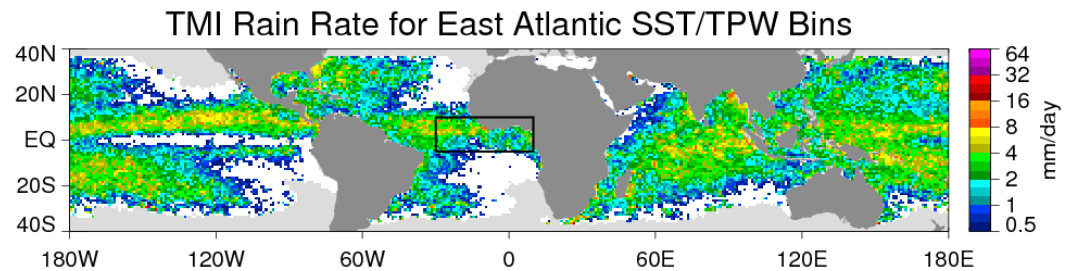
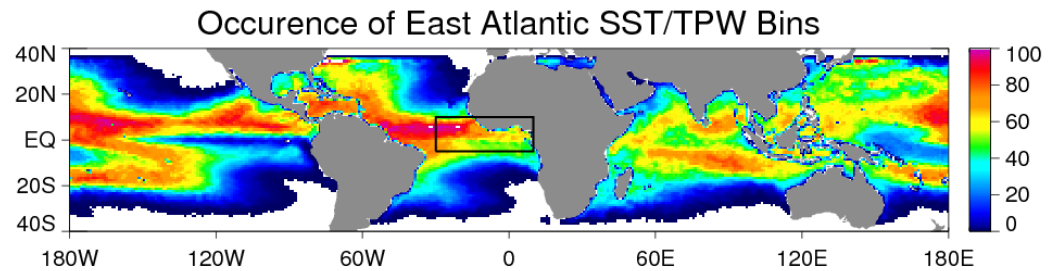
Mean SST = 29.1 degrees
 Mean TPW = 53 mm

Impact of Database Averaging

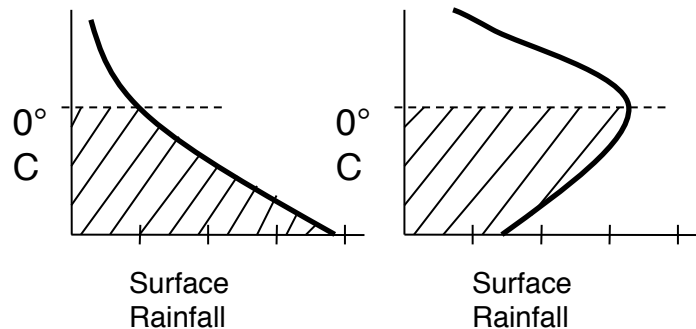
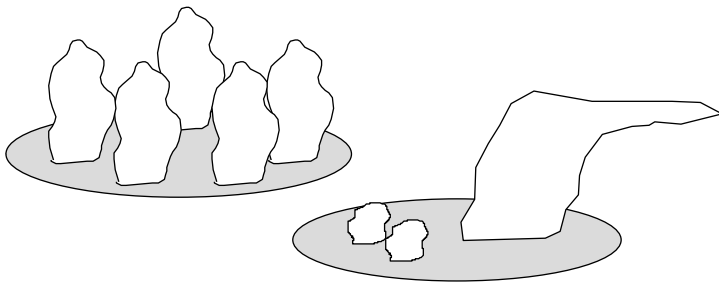
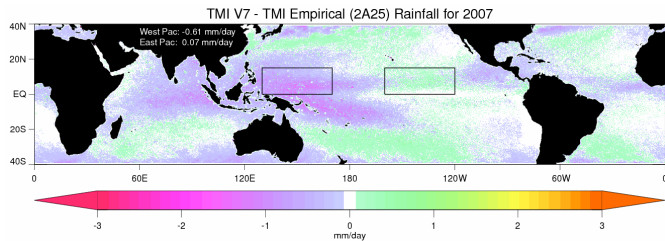
Tropical East Atlantic



Mean SST = 27.3 degrees
 Mean TPW = 48 mm



Potential Sources of Regime Biases



- Microphysics (i.e. DSD)
 - Differences between V7 and Empirical results suggest this is a factor, but may only account for a portion of the differences.
 - GPM DPR should provide information to identify and hopefully resolve this issue
- Inhomogeneity in FOV
 - FOV sizes: ~15km for TMI and ~5km for PR
 - Were the changes to the NUBF correction in 2A25 from V5 to V6 to V7 a significant part of the change in the ENSO response?
 - This could be very significant for TMI and other radiometers due to large footprint size.
 - Preliminary analysis of PR variability within TMI FOV indicates significant differences between East and West Pacific.
- Vertical profile
 - Minor issue for PR/DPR due to surface clutter and extrapolation to surface
 - Potentially a significant issue for TMI since Tb respond to changes in the column integrated water/ice, not the surface precipitation.
 - It is likely that changes in the vertical profile are related to the inhomogeneity.

Conclusions

- The version 7 TMI 2A12 retrieval shows significant improvements in the detection and retrieval of light rain as well as a mean rain rate distribution that agrees much better with PR.
- Significant regional biases remain between the v7 TMI and PR retrievals with the TMI producing substantially more rainfall in the tropical East Pacific and less in the East Atlantic.
- **The current SST and TPW stratification of the GPROF a priori database is not sufficient to capture regime-dependent differences in rain systems.** Given the limited information content of the radiometer Tb, it is likely that other sources of information will need to be incorporated.
- **It appears that regime-dependent differences in the bulk DSD properties over ocean is a factor for the PR estimates.** This has the solution of waiting for the launch of GPM and the DPR.
- **Changes in the response of the PR estimates to ENSO with algorithm version remains a significant concern.** It may be due at least in part to DSD variability, but other factors such as the NUBF correction need to be explored.
- Comparisons with the latest CloudSat profile retrieval suggest that light rain below the PR detection threshold is an issue, particularly over low TPW regimes, but it is less than originally thought (~5% globally).