Tropical Rainfall Regimes: Issues for TRMM PR Rainfall Estimation

by

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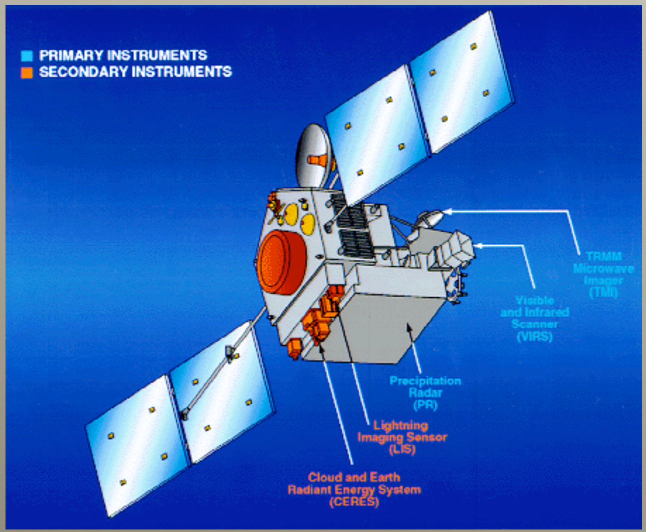
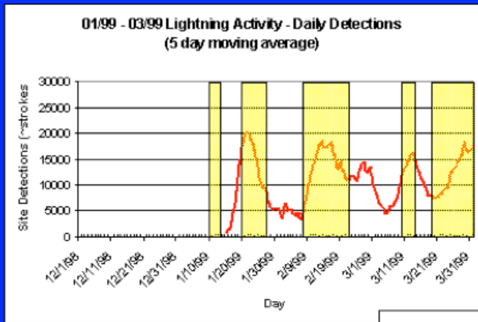


PMM Meeting
Salt Lake City
October 2009

•We are using ground-based polarimetric radar data from three field campaigns, TRMM-LBA (1999), NAME (North American Monsoon Experiment; 2004), and AMMA/NAMMA 2006-2007 to characterize the physical nature of precipitation in these regions (tropical Brazil, Mexico and W. Africa respectively).

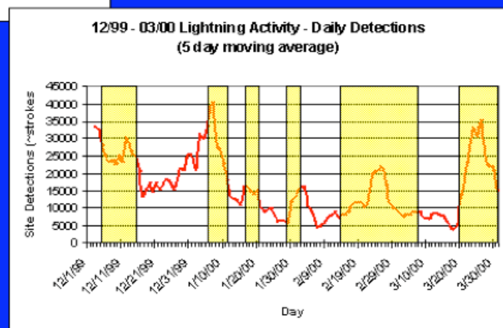
•We focus on comparing rain rates derived from the TRMM PR against those derived from ground based polarimetric radar data. Statistics are built up for TRMM by sampling specific years within the TRMM climatology that are deemed similar to the conditions sampled during the field campaigns. *In this way we hope to contribute to the study of over land PR rain retrievals.*

TRMM-LBA



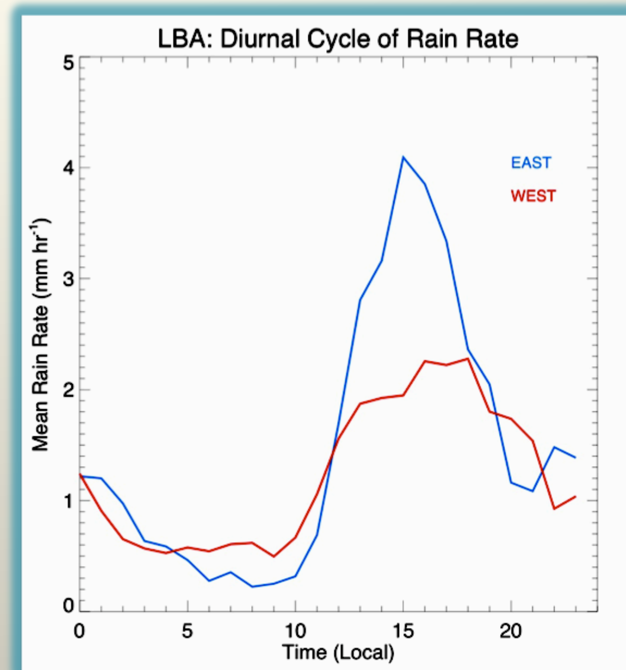
Brazilian Lightning Detection Network (BLDN):

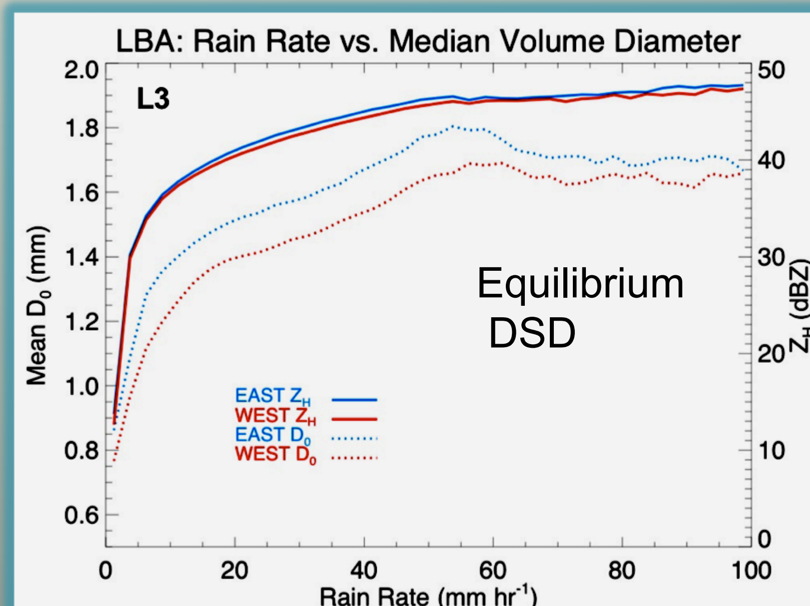
- Oscillations apparent
- East (west) anomalies =more (less) lightning.



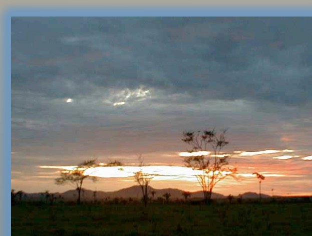
= East anomaly* regime

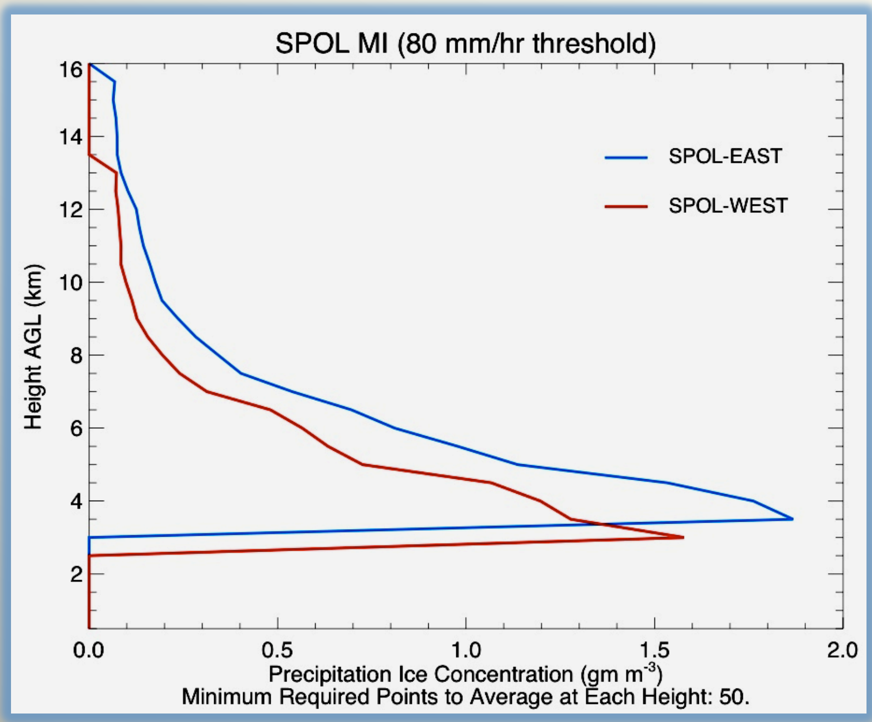
*as defined by wind





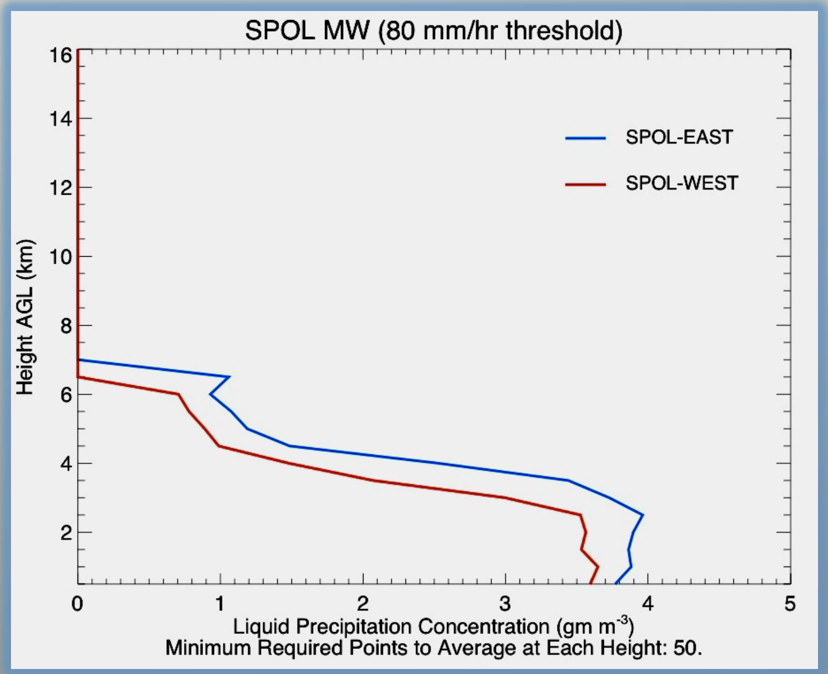
East-West Regimes found in TRMM-LBA. East regime associated with high CAPE, vigorous convection and frequent lightning. West regime associated with lower CAPE, weaker convection and lower flash rates. January-February 1999. 10-15 day cycle.

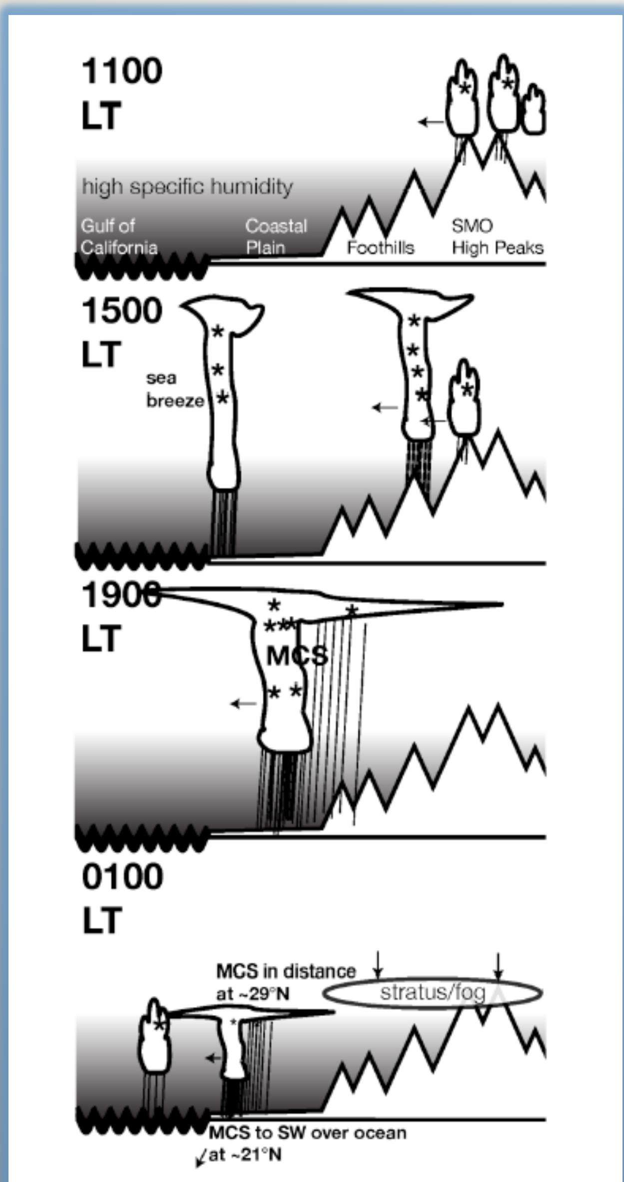




Ice and water mixing ratio profiles from TRMM-LBA

East regime has higher mean mixing ratios compared to West regime





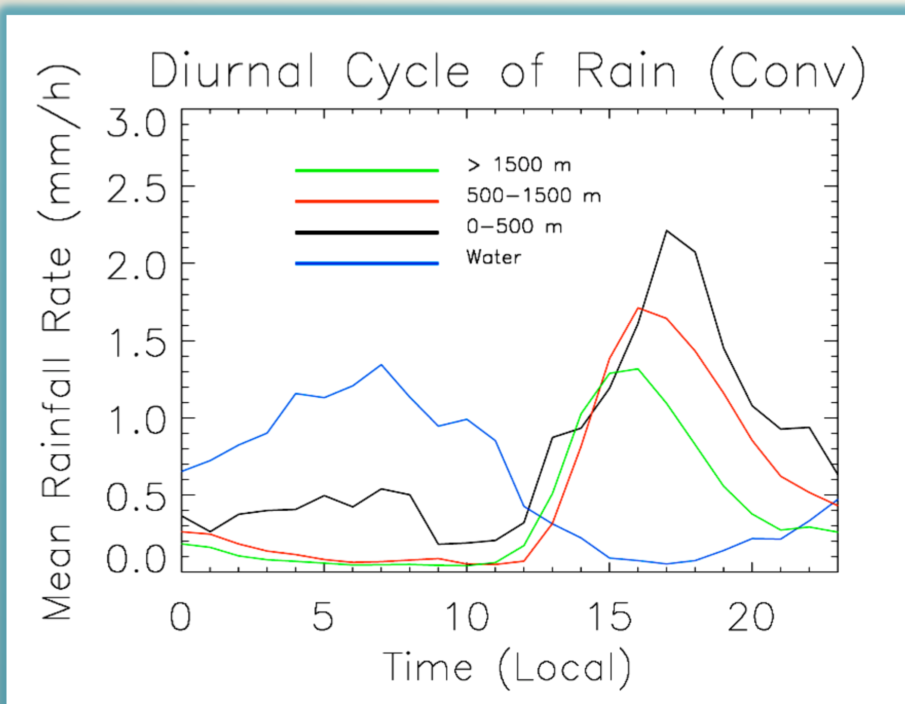
NAME 2004

Conceptual Model

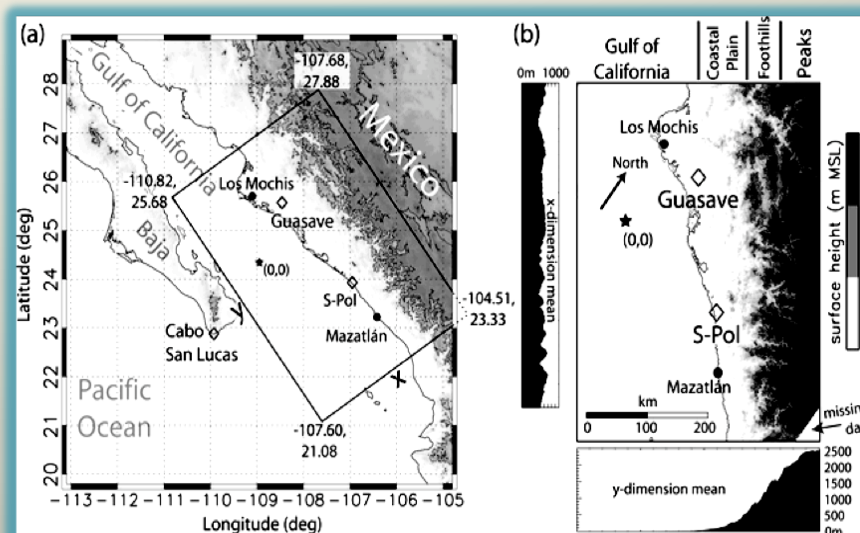
Lang et al. (2007), Nesbitt et al. (2008), Rowe et al. (2008)

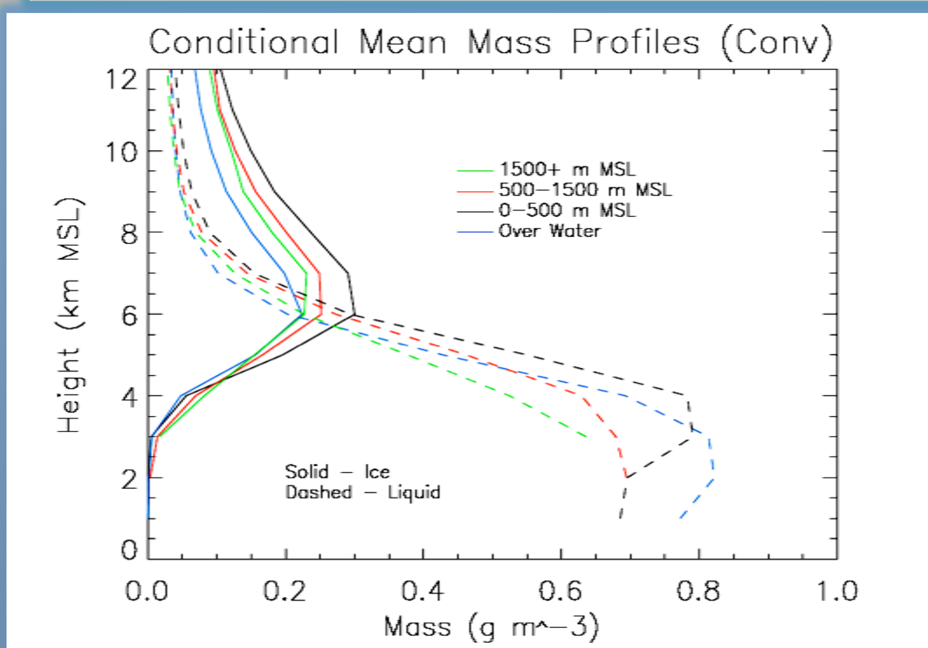
Convection forms over highest terrain, then moves westward

NAME affords an opportunity to compare PR rainfall against ground based measurements in a region of strong topographical variation

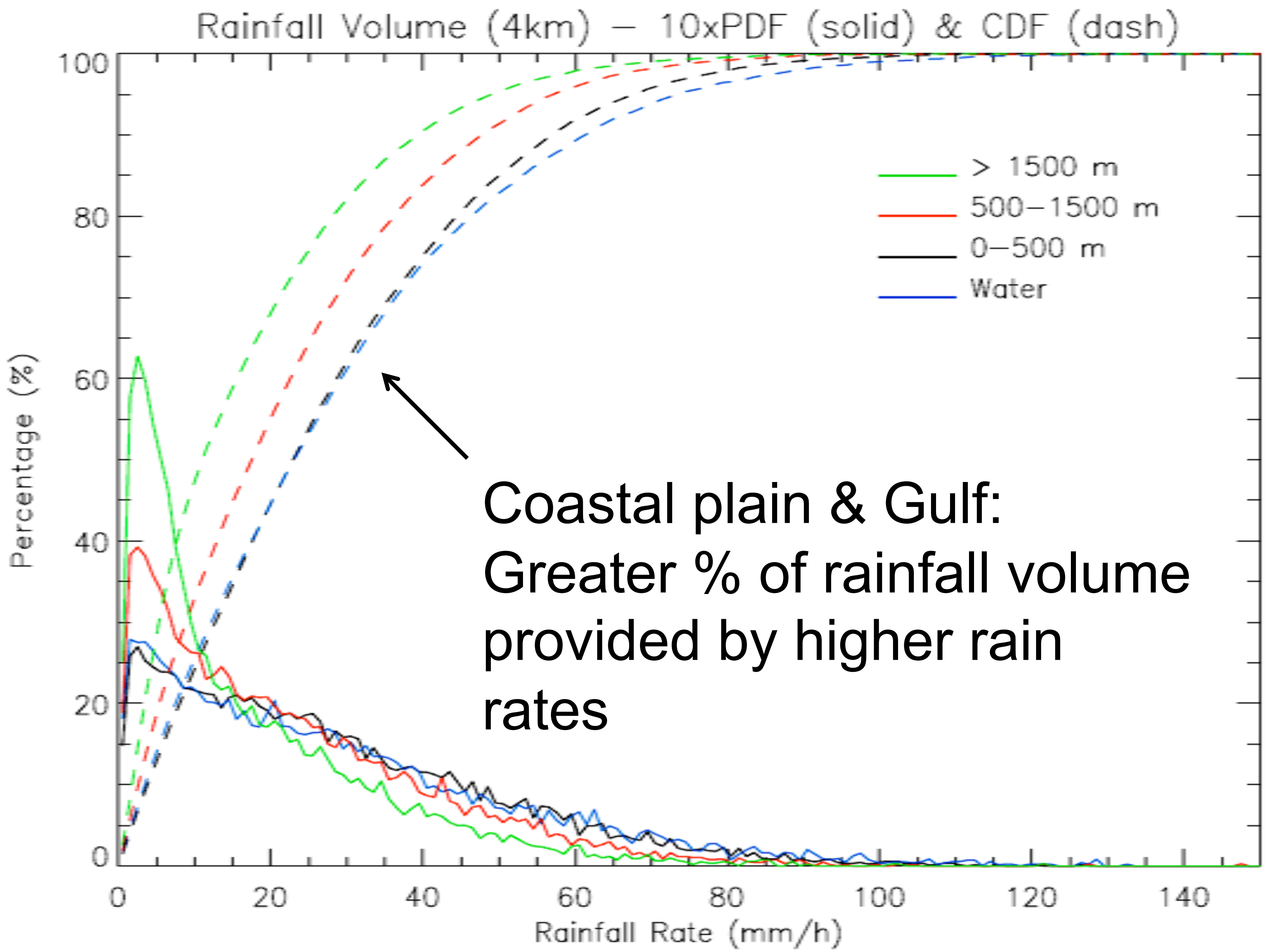


•Strong topographical influence on precipitation intensity and structure.

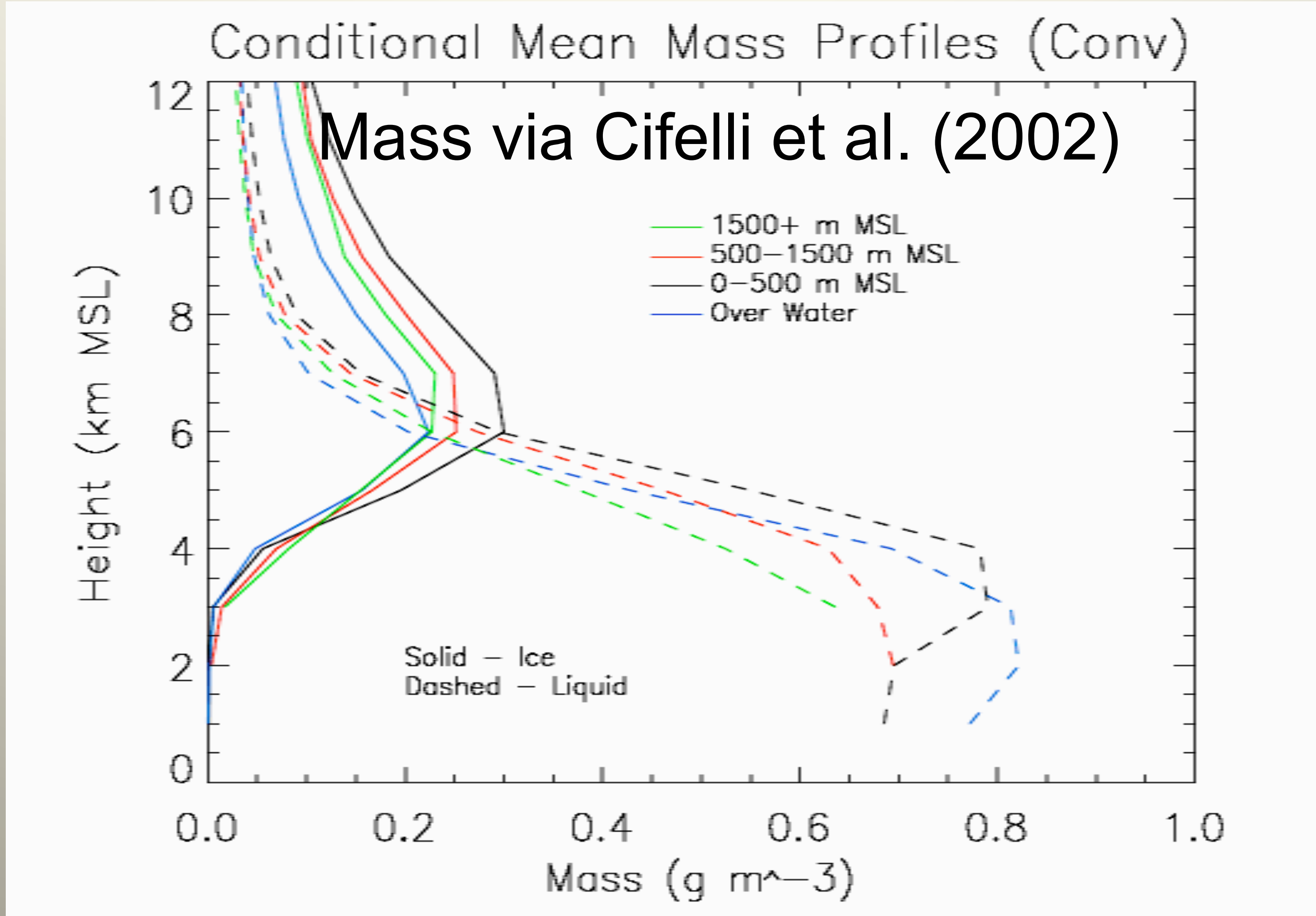




<u>For both NAME and LBA, observations suggest equilibrium DSD indicated by near constant D_0 values at high rain rates/reflectivities.</u>



Coastal plain & Gulf:
Greater % of rainfall volume provided by higher rain rates



Gulf - least amount of ice mass, but more water mass

Land – Ice & water mass varies inversely with elevation

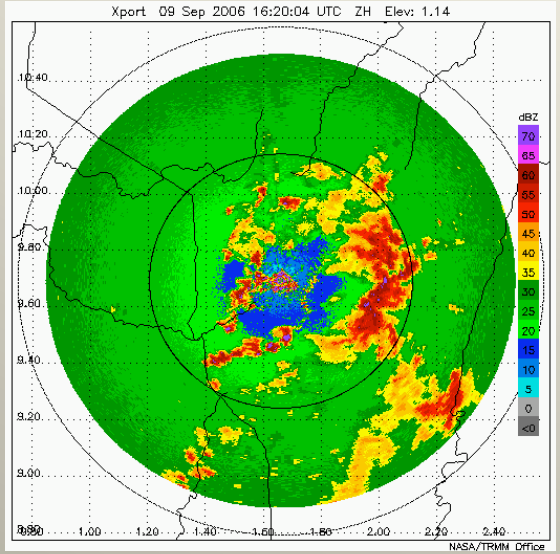
African Monsoon Multidisciplinary Analyses (AMMA) and NAMMA

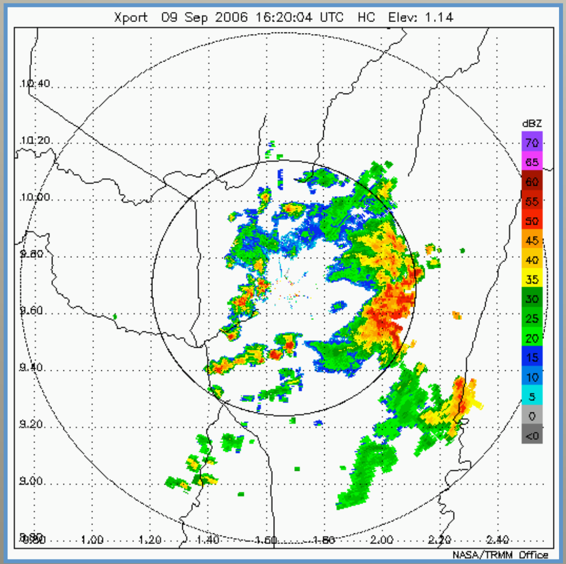
- Special Observing Period summer/fall 2006
  - Numerous ground observations
    - Rain gage networks
    - Numerous radars including MIT, N-Pol, Toga (NAMMA)
    - Ronsard (C-band) and **XPort (X-band)**

XPort

- Polarimetric X-band radar operated by France
- 2+ seasons (2006-2007)
- Have focussed on 2006 season to date
  - QC work
    - 2nd trip
    - Reflectivity calibration

XPort: QC

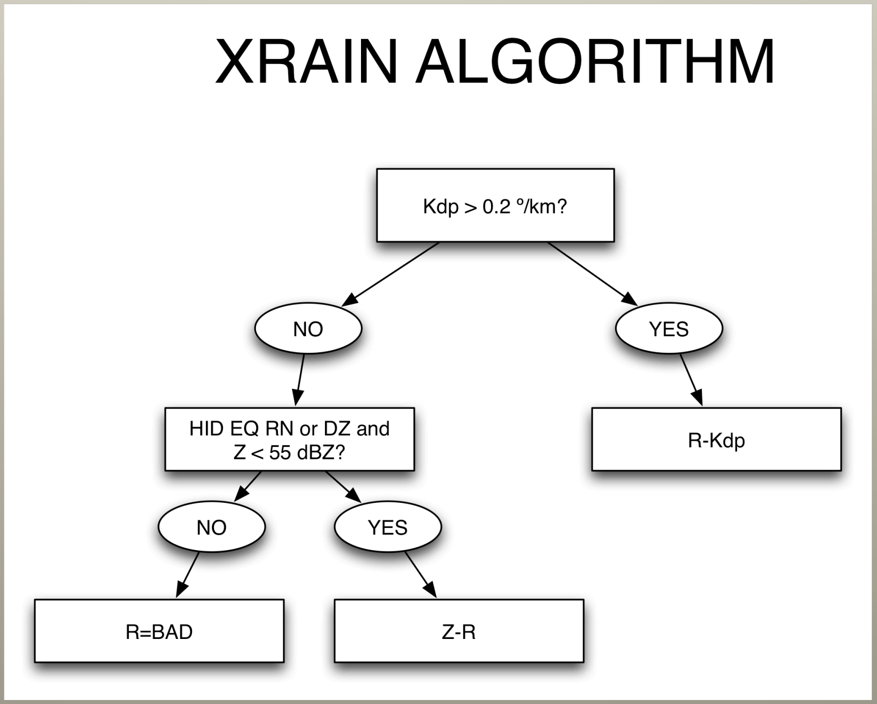




- Calibration
  - Used TRMM overpasses to calibrate (only 2)
  - Horizontal offset: **14.8**
  - Vertical offset: **17.4**
- QC'd using polarimetric thresholds
- 2nd trip detection: vertical continuity
- Attenuation Correction: methodology outlined in Carey et al. (2000)
  - Still significant areas of complete attenuation
- After QC, the Xport dataset is proving valuable in the study of W. Africa convection

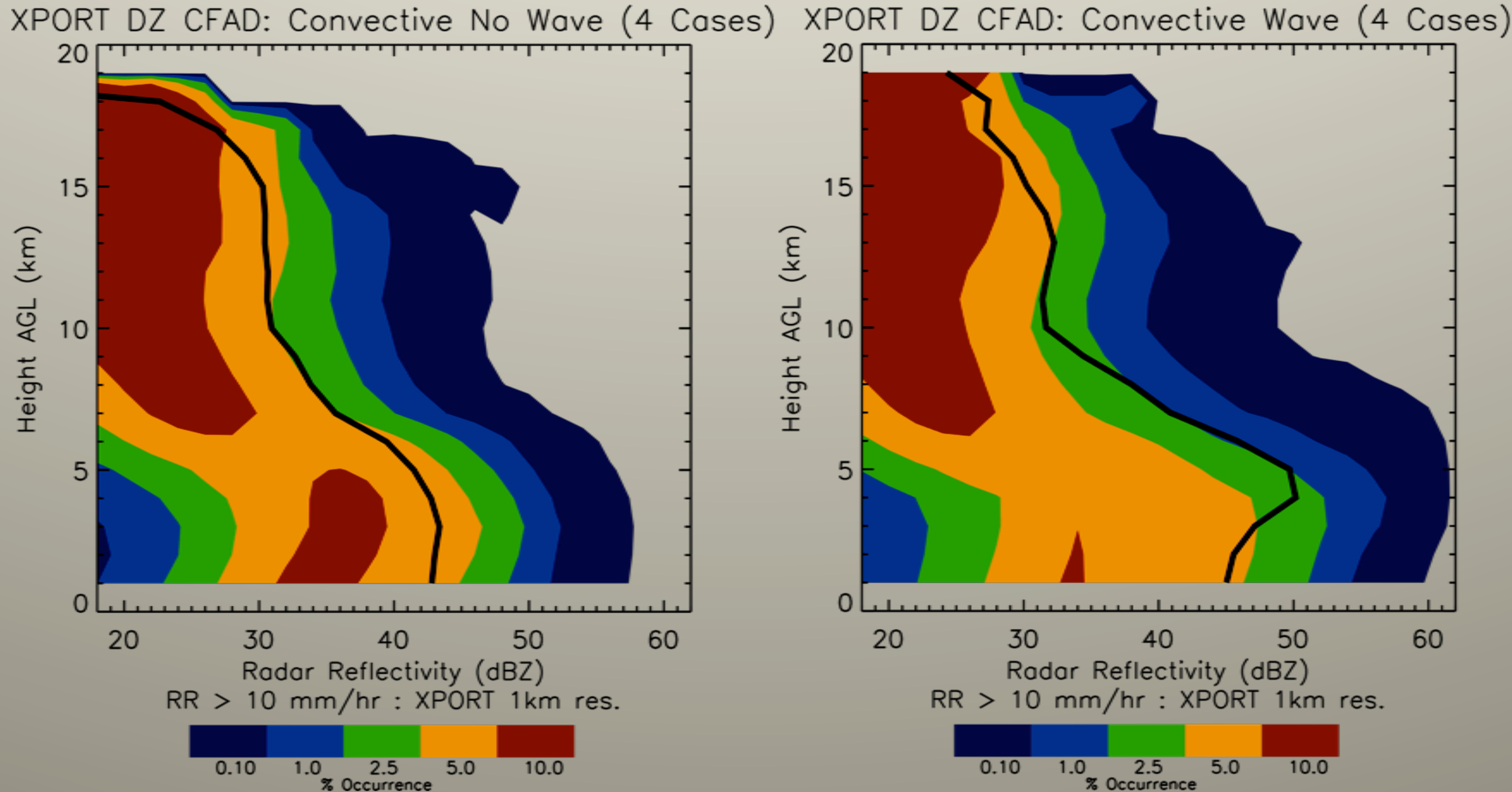
XPort

- Rain rate estimation
- Blended algorithm
  - $Z=468R^{1.39}$ (Moumouni et al., 2008)
  - $R=20K_{dp}^{0.8}$ (Gosset, disdrometer comparisons)



West Africa: XPort

- Study regime microphysics in Benin with the dual-pol XPort
  - Influence of African Easterly Waves on convection (wave vs. no wave, 3-5 day period)
  - CFAD; reflectivity frequency plotted as function of height, then contoured. Mean profile indicated as well (solid line).



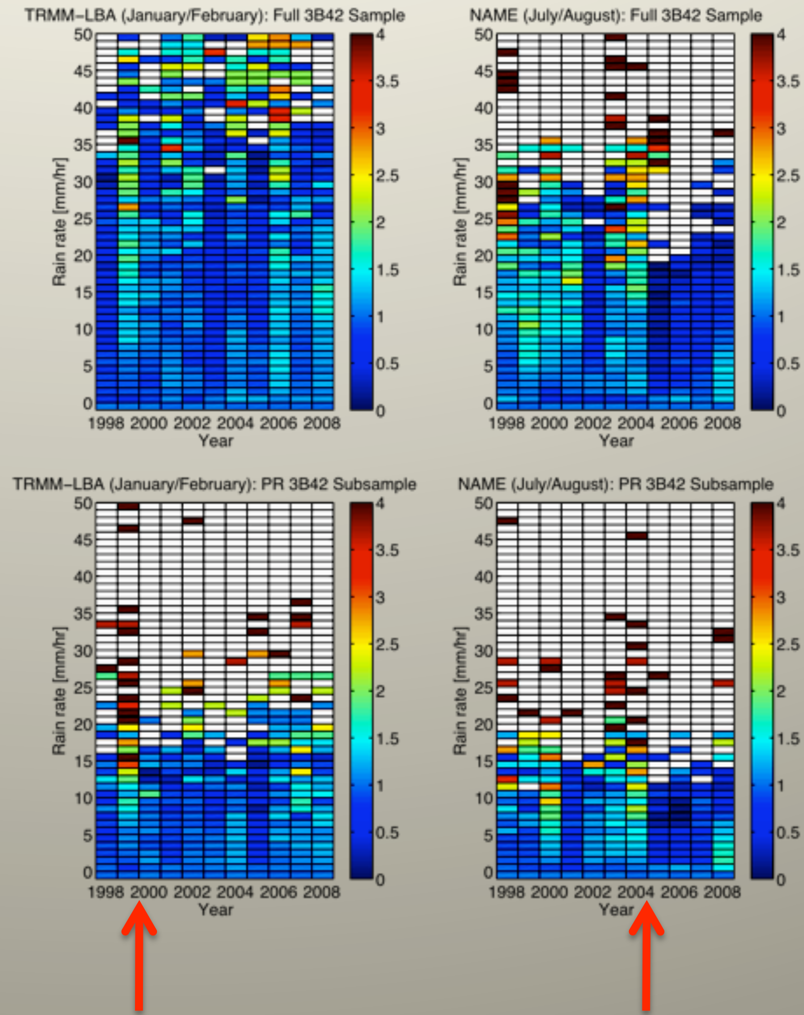
Now to compare ground based data to TRMM PR observations…..

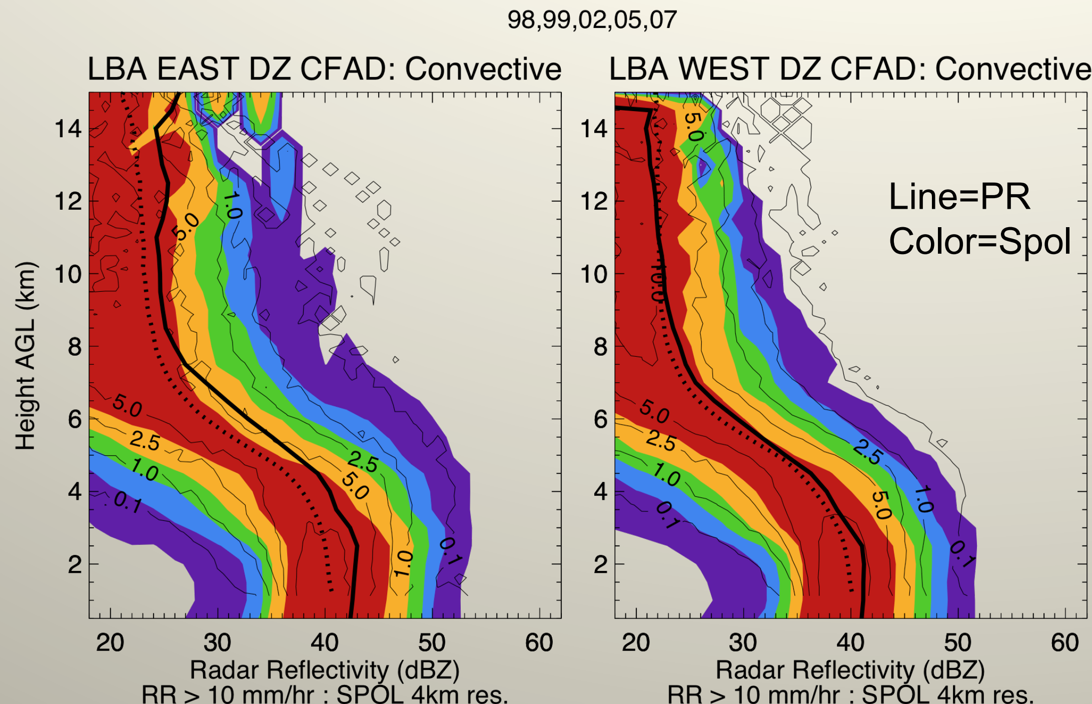
Compare field campaign reflectivity data to PR reflectivity; compare rain rates and Z-R relationships as well

Field campaign is an obvious "snapshot"; insufficient overpasses in any campaign for meaningful statistics

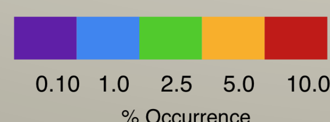
Identify field campaign "like years" from 3B42

Identified a 5 year period for LBA intercomparison and another 5 year period for NAME; NAMMA will be done next





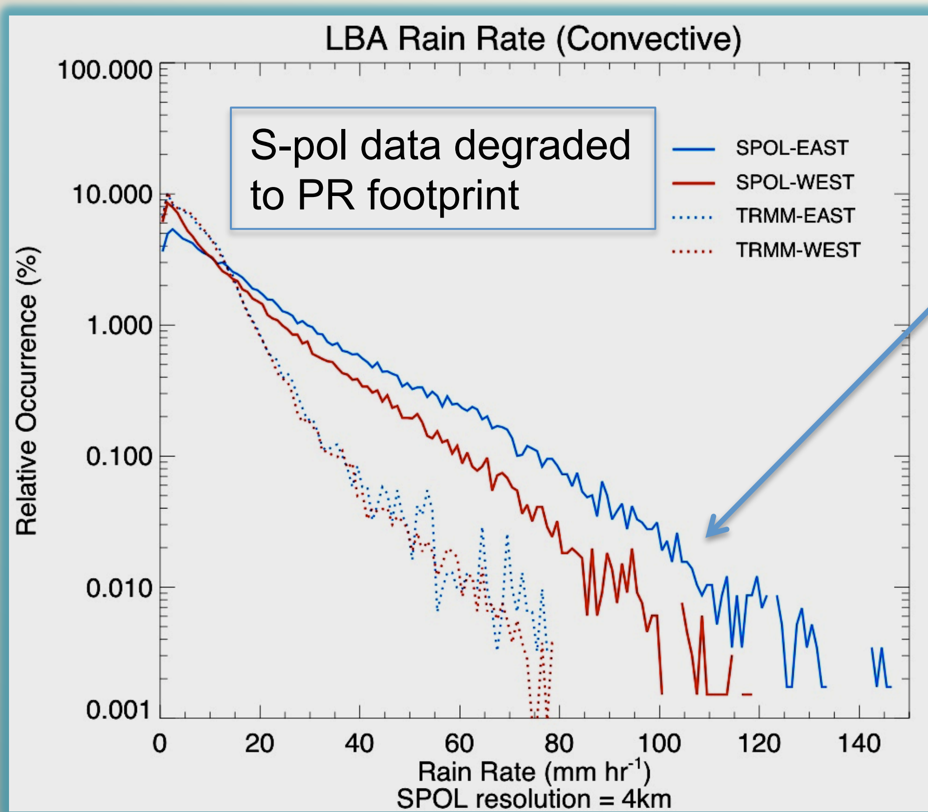
S-pol resolution has been degraded



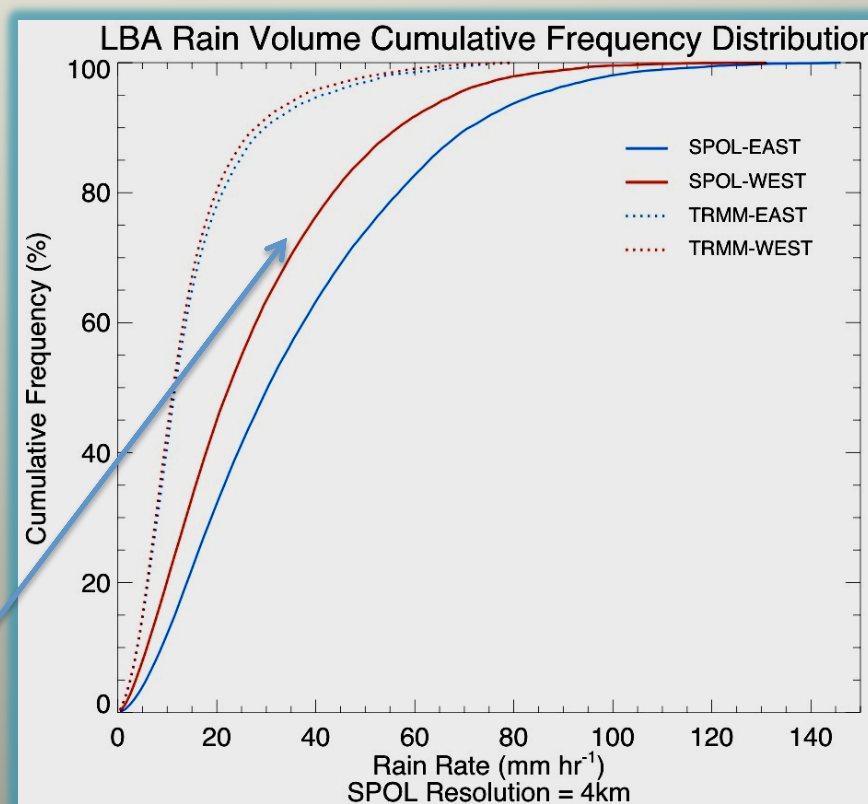
Mean TRMM reflectivity values are somewhat lower compared to S-pol below 7-8 km. S-pol data were thresholded at 17 dBZ as well to match PR.

Reflectivity differences below 7-8 km possibly a result of attenuation correction issues for the PR (wet ice, Mie effects), or other factors? Z differences are larger in E regime compared to W regime where convection is more intense.

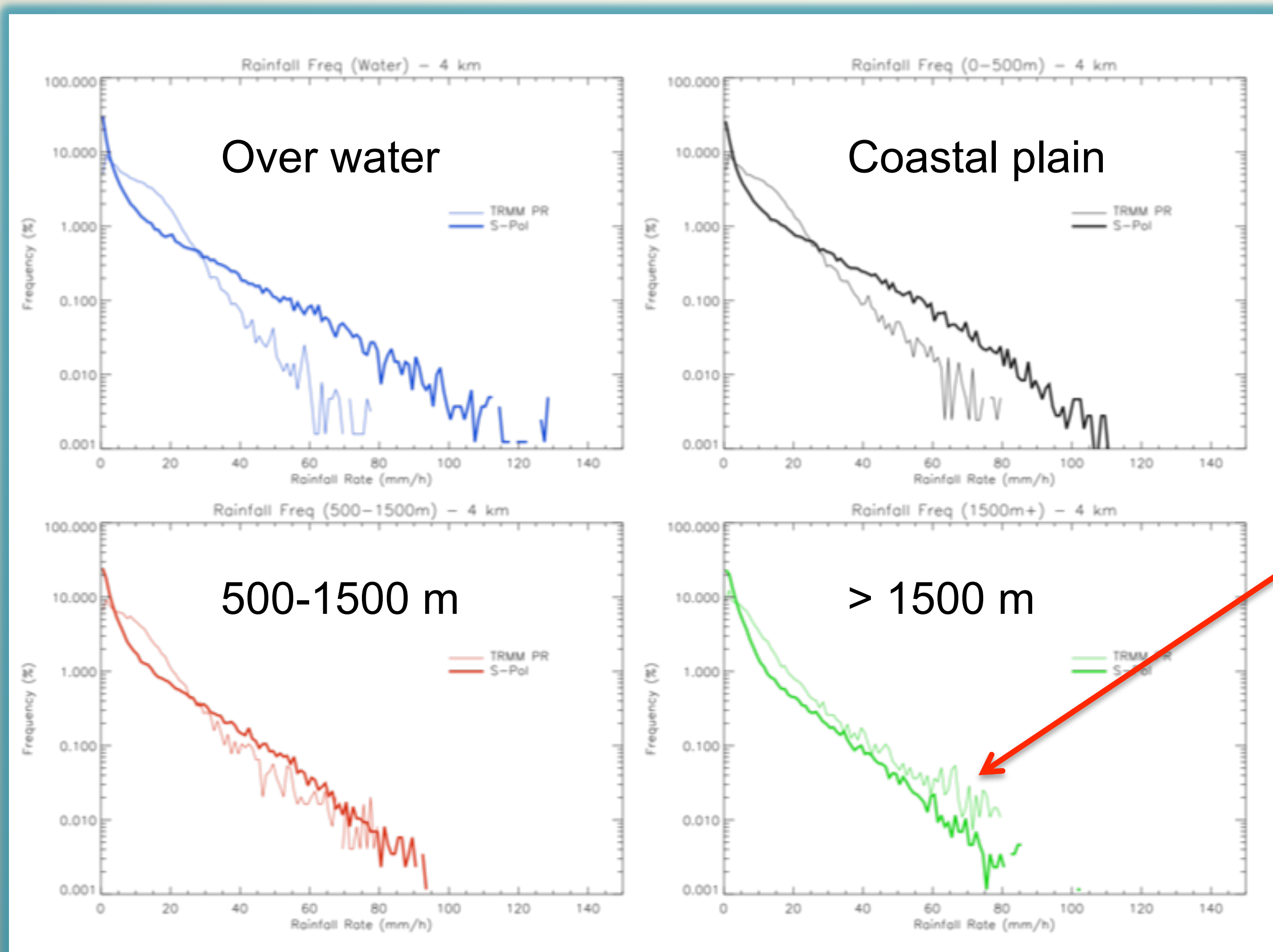
Turn now to examination of rain rates between PR (5 year subset) and S-pol



TRMM PR does not indicate the high rain rates observed in the S-pol data



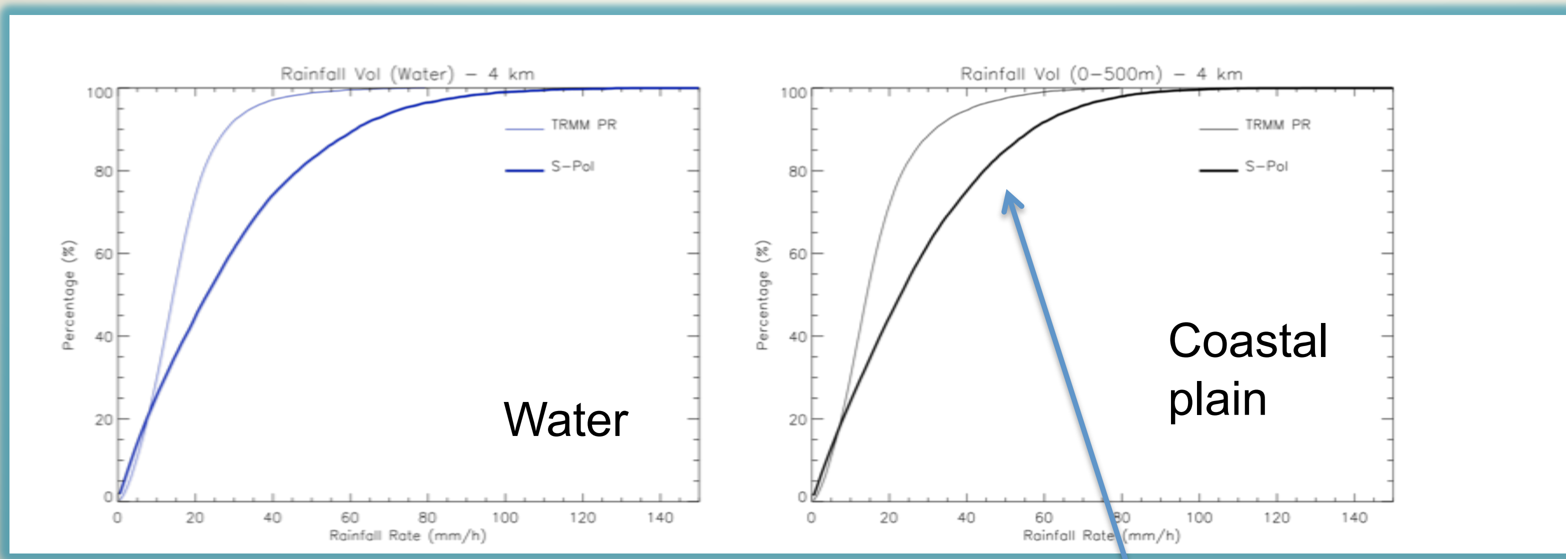
TRMM PR places more rain volume at lower rain rates compared to the ground based radar.



And the same analysis for NAME

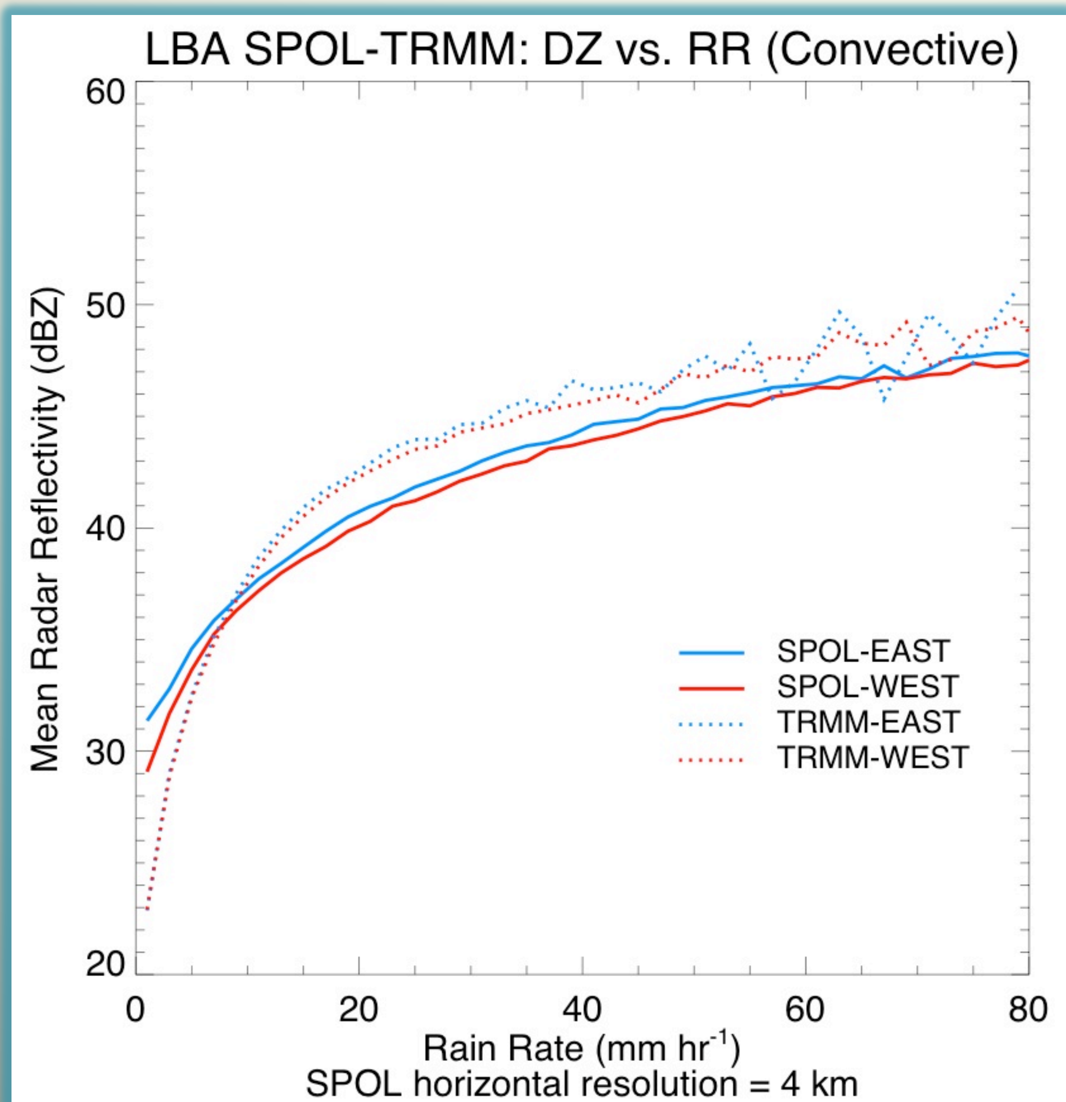
S-pol native resolution less than PR at long ranges required to reach high terrain

NAME shows similar behavior, especially over water and the coastal plains.
At higher elevations, TRMM PR and S-pol rain rate spectrum is in better agreement.
This may be due to reduced S-pol resolution (compared to PR) at long ranges required to sample storms over the higher terrain. S-pol may not be able to resolve intense, small scale rainfall.



For NAME, TRMM PR places more rain volume at lower rain rates compared to the ground based radar. Consistent with finding for TRMM-LBA.

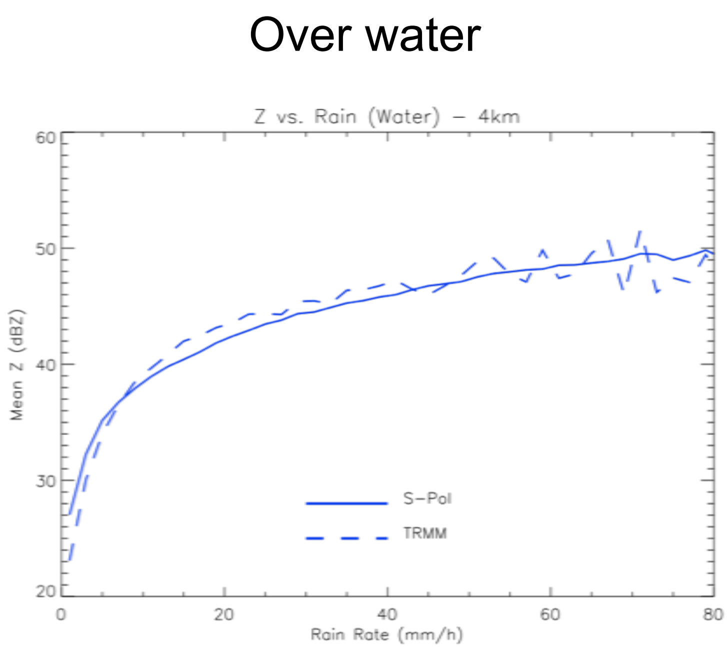
10-15% differences in rain volume seen for this particular comparison. NAME and LBA cdf's are similar.

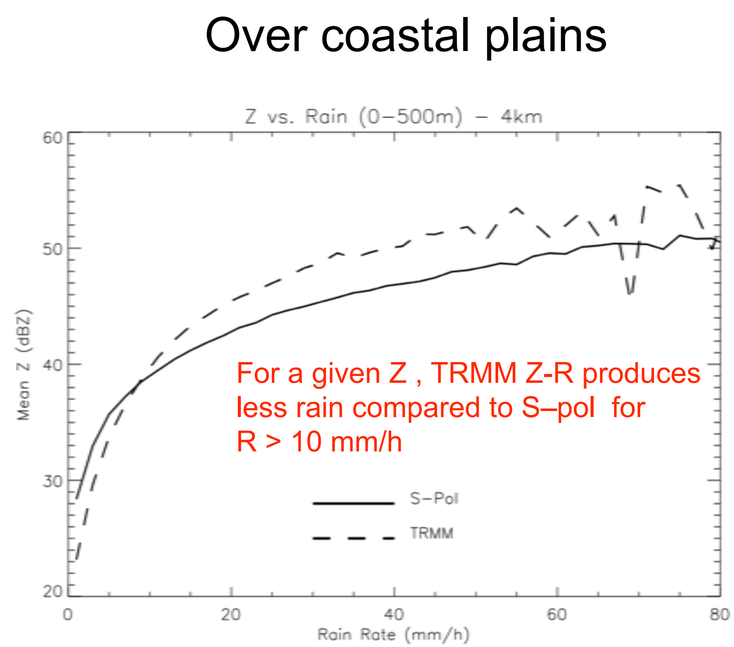


Z-R plot for LBA
Solid--S-pol
Dash--PR

Above 10 mm/h,
S-pol derived rain rates are larger than those from PR, for
a given reflectivity.

NAME





Z-R relationships in fair agreement over water.

Z-R relationships in poorer agreement over adjacent coastal plains.

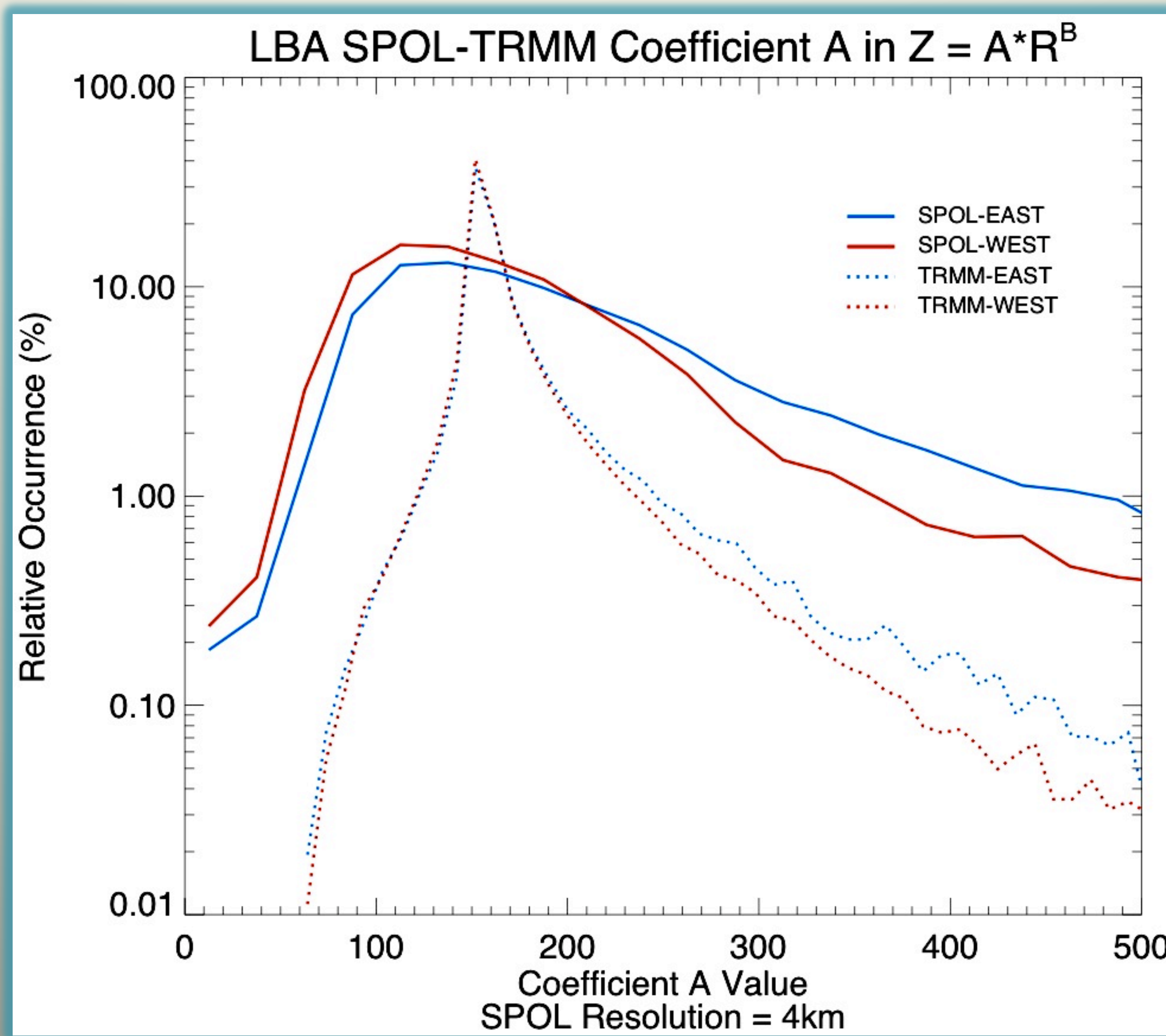
Z-R

$$R = 10^{(dBZ - 10\log A)/10b}$$

Field campaign data reveal different Z-R relationships compared to that estimated by TRMM.

For the LBA and NAME (land) regions, the value of the **A** coefficient is smaller in the ground based data compared to PR. Low value of A is consistent with the diagnosed microphysical situation (near constant D_0; coalescence/collisional breakup).

Smaller A implies a larger rain rate for a given Z. Comparison of rain rate pdf's support this.


LBA SPOL-TRMM Coefficient A in Z = A*R^B
100.00
10.00
1.00
0.10
0.01
0
100
200
300
400
500
Relative Occurrence (%)
Coefficient A Value
SPOL Resolution = 4km
SPOL-EAST
SPOL-WEST
TRMM-EAST
TRMM-WEST

Seasonal variations of A coefficient

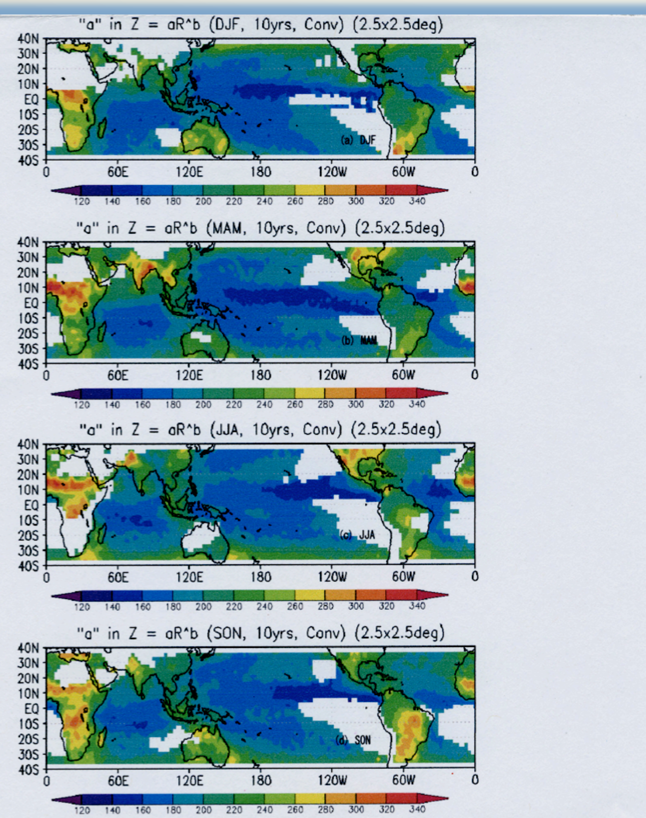


Fig. 7. Seasonal variation of global *a* distribution as a representation of DSD climatology from TRMM PR.

From Kozu et al. (2009)
J. of the Met. Soc. of Japan
Vol. 87A, 53-66.

Its obvious that TRMM PR gets a lot of the precipitation physics right…

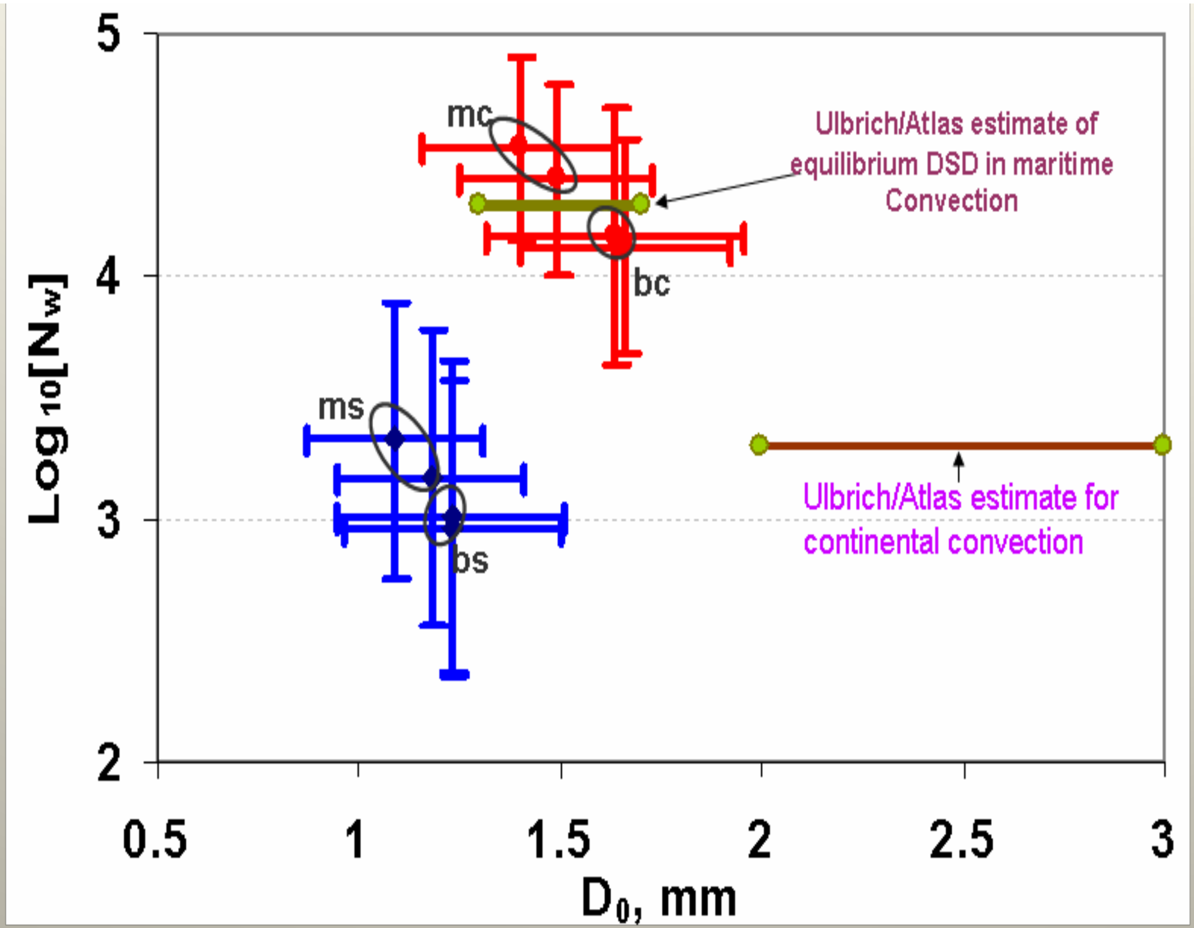
Implications for Z-R estimator derived by TRMM PR………

Field campaigns have revealed sub-seasonal variability of rain physics that lead to differences in the TRMM rain pdf's and Z-R relationships compared to those derived by ground-based radar.

Single polarization, radar-based rain estimates from PR are limited in capturing the full physics of the DSD.

Important to incorporate information on the "meteorological regime" to refine DSD information and resulting Z-R relationships (k-Z relationships). This is being incorporated into GPM DPR algorithms. Topographical variability also an issue.

Work currently underway on this activity……….



Mean of $\log_{10}(N_W)$ versus mean of D_0 derived for convective (red) and stratiform rain types rain (blue), together with their respective standard deviations (±1σ). The units for N_w are in mm^{-1} m^{-3}. The monsoon/build-up convective, and monsoon/build-up stratiform are, denoted by 'mc'/'bc', and 'ms'/'bs', respectively. The two solid dots within each circled area represent land or ocean regions which have not been distinguished by different colors. Note that there is no significant difference in the means for convective rain between land or ocean regions during the build–up regime (solid dots are virtually indistinguishable within the circled region marked as 'bc'). Same is true for stratiform rain (solid dots are very close together within the circled region marked 'bs'). However, there are some differences between land and ocean regions for monsoon convective (solid dots are separated within the circled region marked 'mc' with the mean D_0 value being larger over ocean than over land, see Table 1). Same is true for stratiform rain (solid dots being separated within the circled region marked as 'ms').

Summary

- TRMM providing unprecedented information on tropical rainfall
- It is well known that TRMM PR captures the physical characteristics of rainfall over oceans quite well
- Field campaigns have revealed sub-seasonal variability of rain physics that lead to differences in the TRMM rain pdf's and Z-R relationships compared to those derived by ground-based radar
- Single polarization, radar-based rain estimates from PR are limited in capturing the full physics of the DSD.
- Propose that information on the "meteorological regime" be incorporated to refine DSD information and resulting Z-R relationships (k-Z relationships). This is being invoked for GPM DPR retrievals.
- Work currently underway on this activity.

Acknowledge long term support from NASA TRMM and PMM programs

Near term activities

- Analyze Darwin polarimetric data from 9 monsoon seasons
  - Nov. – Feb. 1999-2007 LAND vs. OCEAN
  - Comparison with TRMM PR 10-year climatology (1999-2008)
  - Will limit biases due to climo. vs. single field season
  - Compare reflectivity profiles, rain rates , DSD parameters (D_0) between regimes and with TRMM
  - Study microphysical differences leading to variability in rainfall and influence on Z-R estimated by TRMM PR

- Will also compare AMMA/NAMMA data (Z, rain rate pdf's) to TRMM PR data as we have done for other tropical locations