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# A STATISTICAL ALGORITHM FOR INFERRING RAIN RATE FROM THE QUIKSCAT RADIOMETER

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# Rain Rate Algorithm

Algorithm provides two products

- Instantaneous rain rate  $> 0.5$  mm/hr
  - 25 km x 25 km spatial resolution
- Global weekly to monthly average rain rates

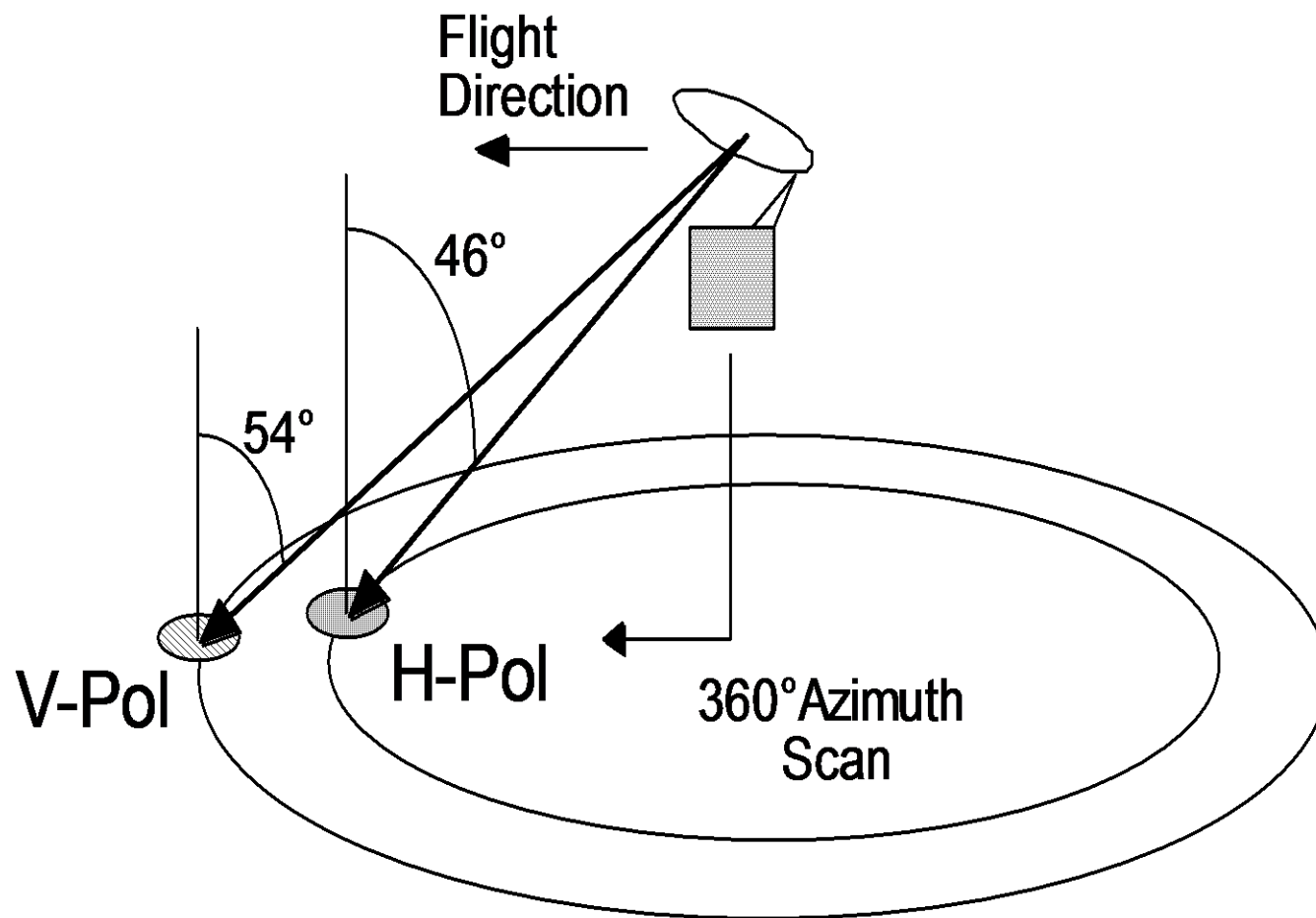
Uses SeaWinds remote sensor on the QuikSCAT satellite

- Microwave brightness temperatures
- Retrieved wind speeds



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# SeaWinds Measurement Geometry





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# Physical Basis of Rain Algorithm



# Brightness Temperature Rain Rate Relationship

- The polarized microwave “excess brightness” ( $\Delta T_{bp}$ ) is proportional to the integrated rain rate

$$\Delta T_{bp} = T_{b\text{meas}}_p - T_{b\text{ocean}}_p - T_{b\text{w.speed}}_p$$

- $T_{b\text{ocean}}$  = ocean background (includes atmos. emissions without rain)
  - based upon 7 year SSMI climatology
- $T_{b\text{w.speed}}$  = wind speed brightness bias

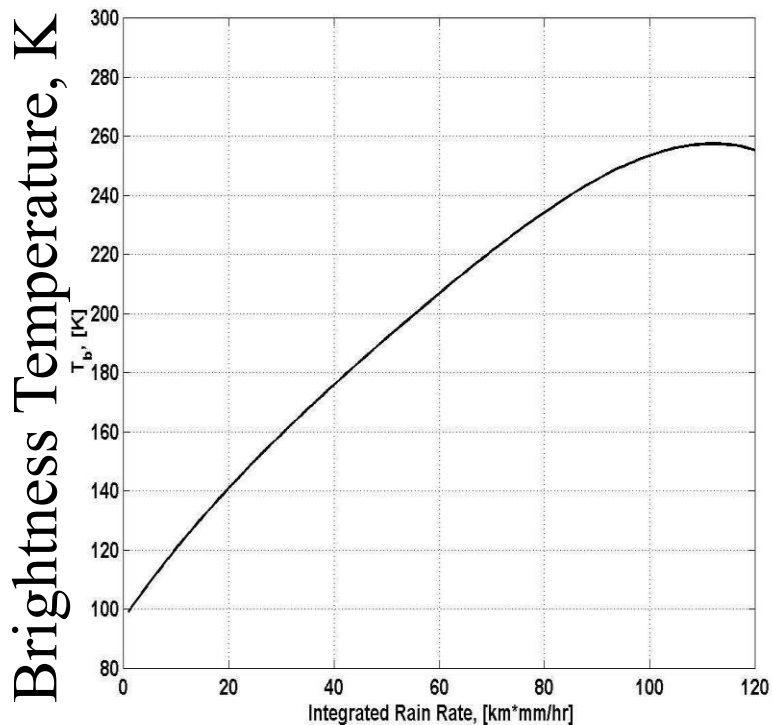


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# Tb-RR Relationship

## H-pol

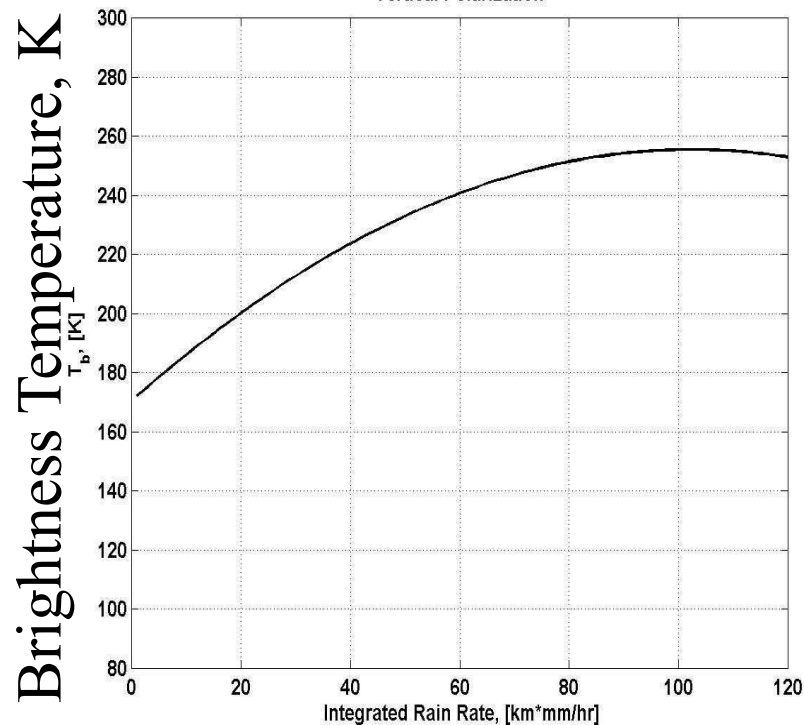
Horizontal Polarization



Integrated Rain Rate (km\*mm/hr)

## V-pol

Vertical Polarization



Integrated Rain Rate (km\*mm/hr)

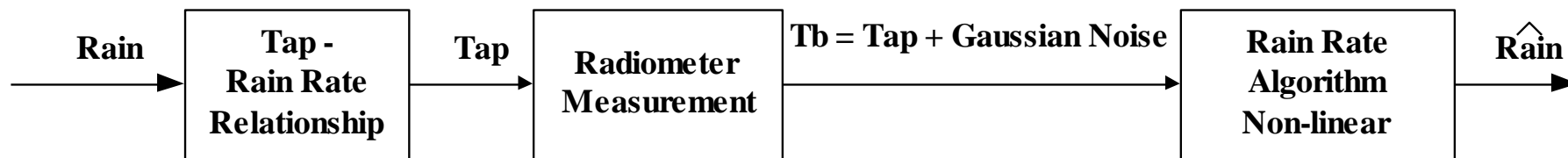


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# Rain Measurement Theoretical Basis



# Block diagram



$$\text{ERROR} = \text{Rain} - \hat{\text{Rain}}$$

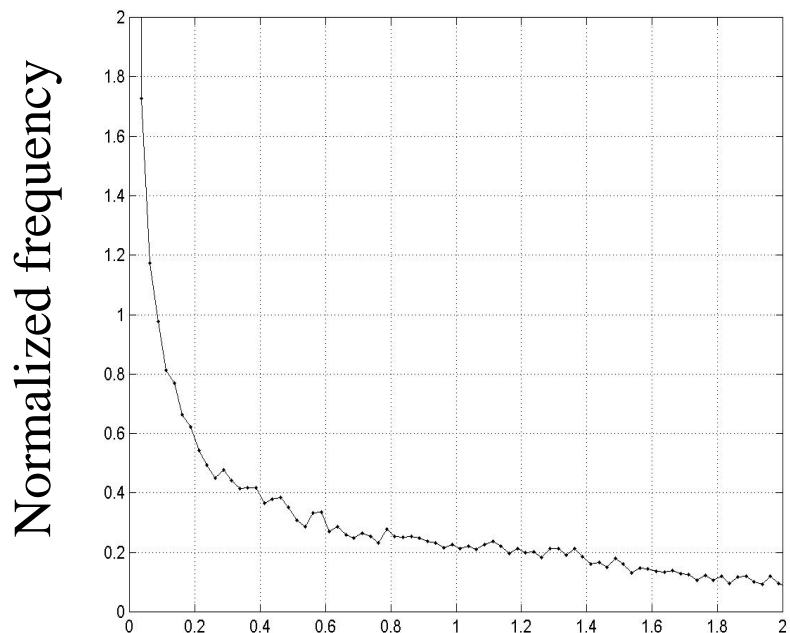


# Monte Carlo Simulation

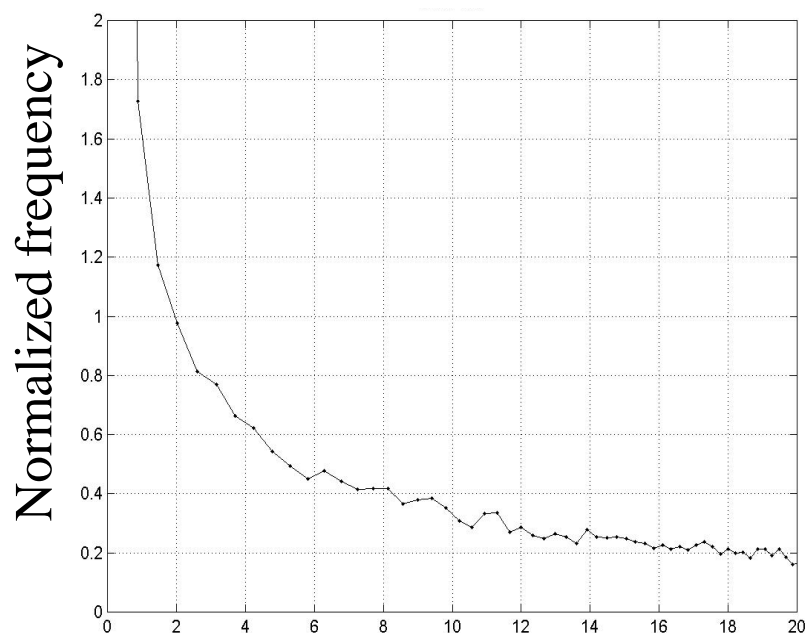
- Assume a rain rate pdf and use the  $T_b$ -RR relationship to simulate "noise-free"  $T_p$ .
- Noisy radiometer measurements ( $T_b$ ) are created by adding Gaussian noise
- Process  $T_b$  using the rain rate algorithm and output an estimated rain rate
- Comparisons are made between the assumed rain rate pdf and the rain rate retrieval pdf



# Ocean Assumed Rain and noise-free Tex



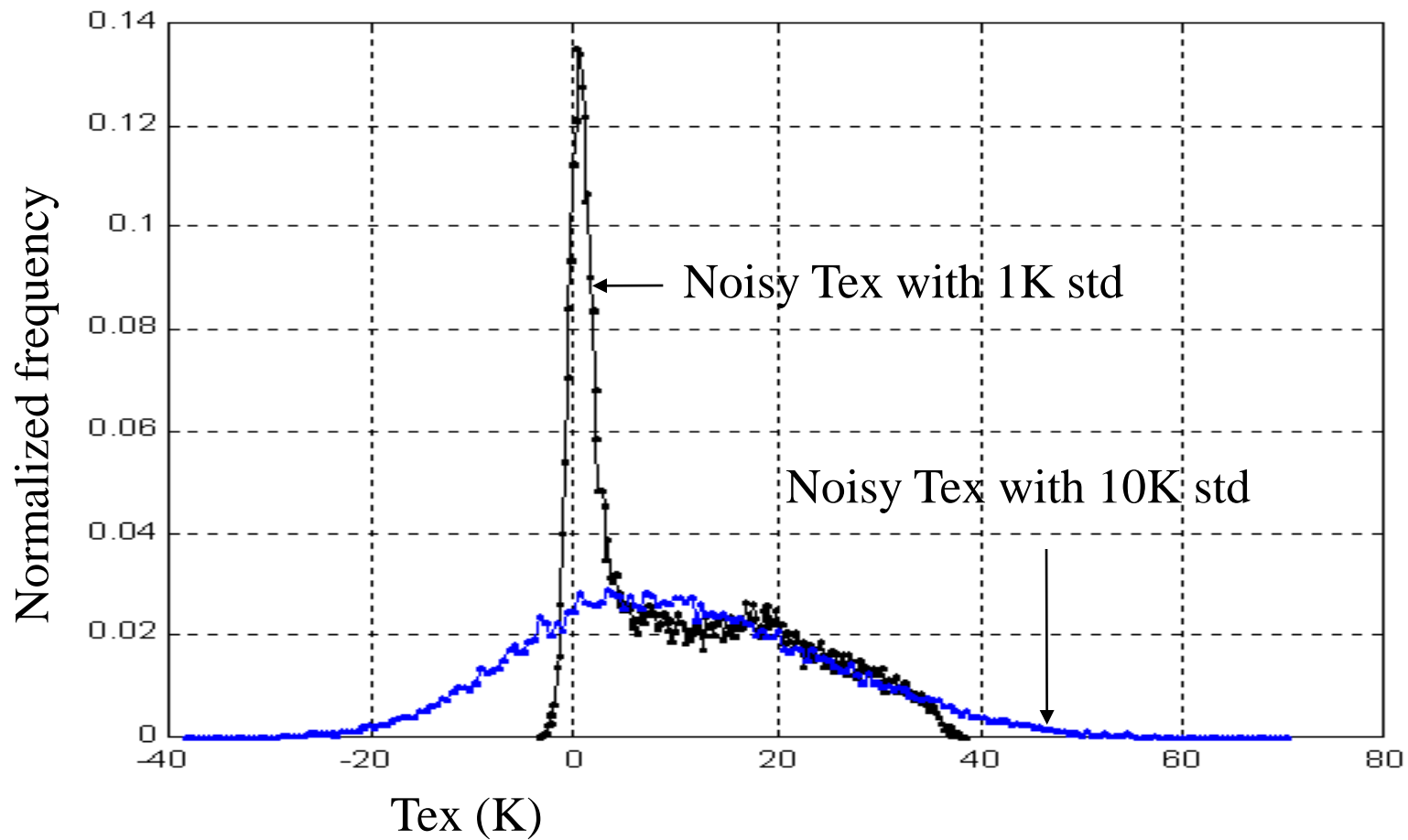
Rain Rate (mm/hr)



Tex (K)

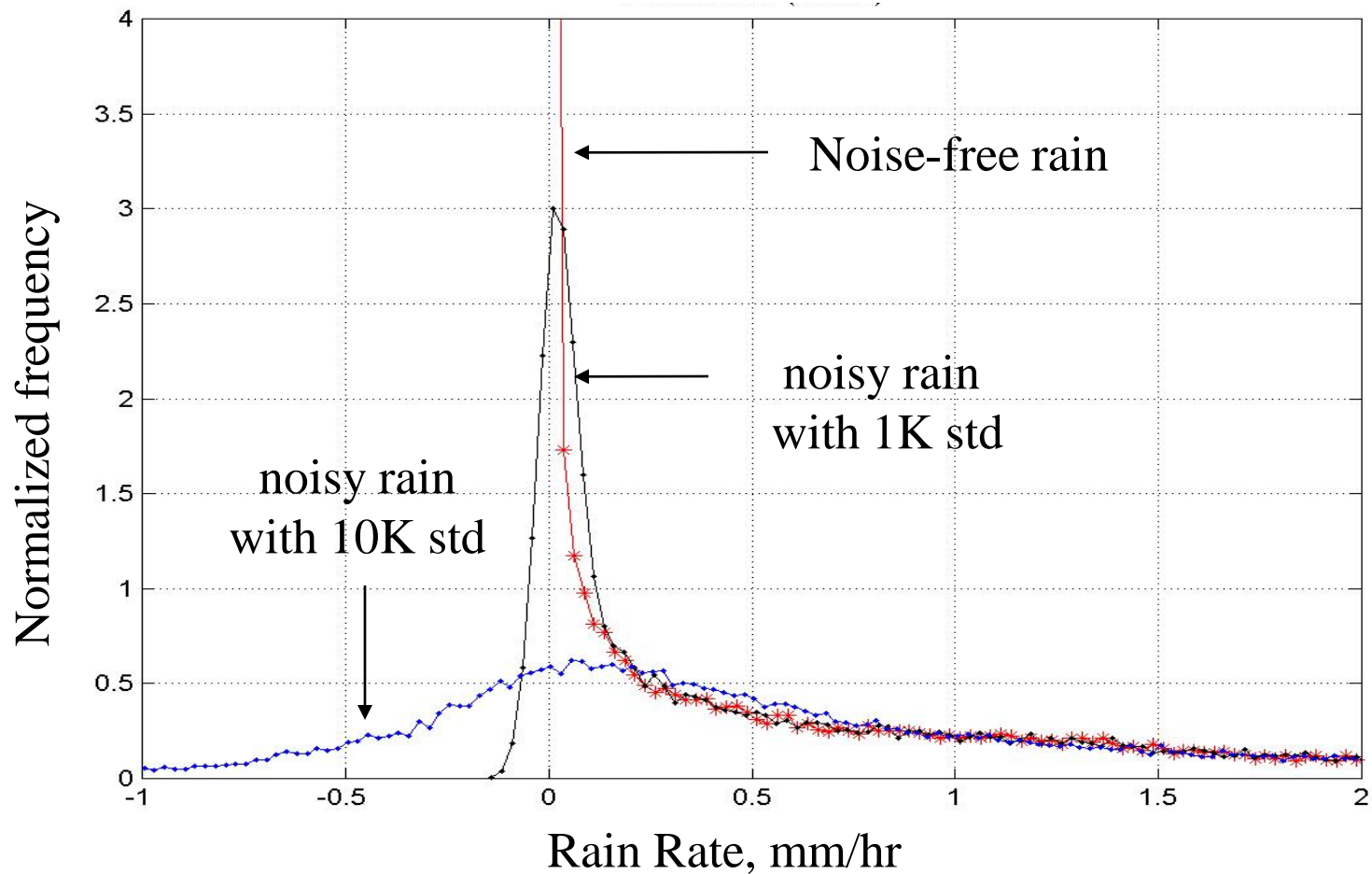


# Noisy Tex



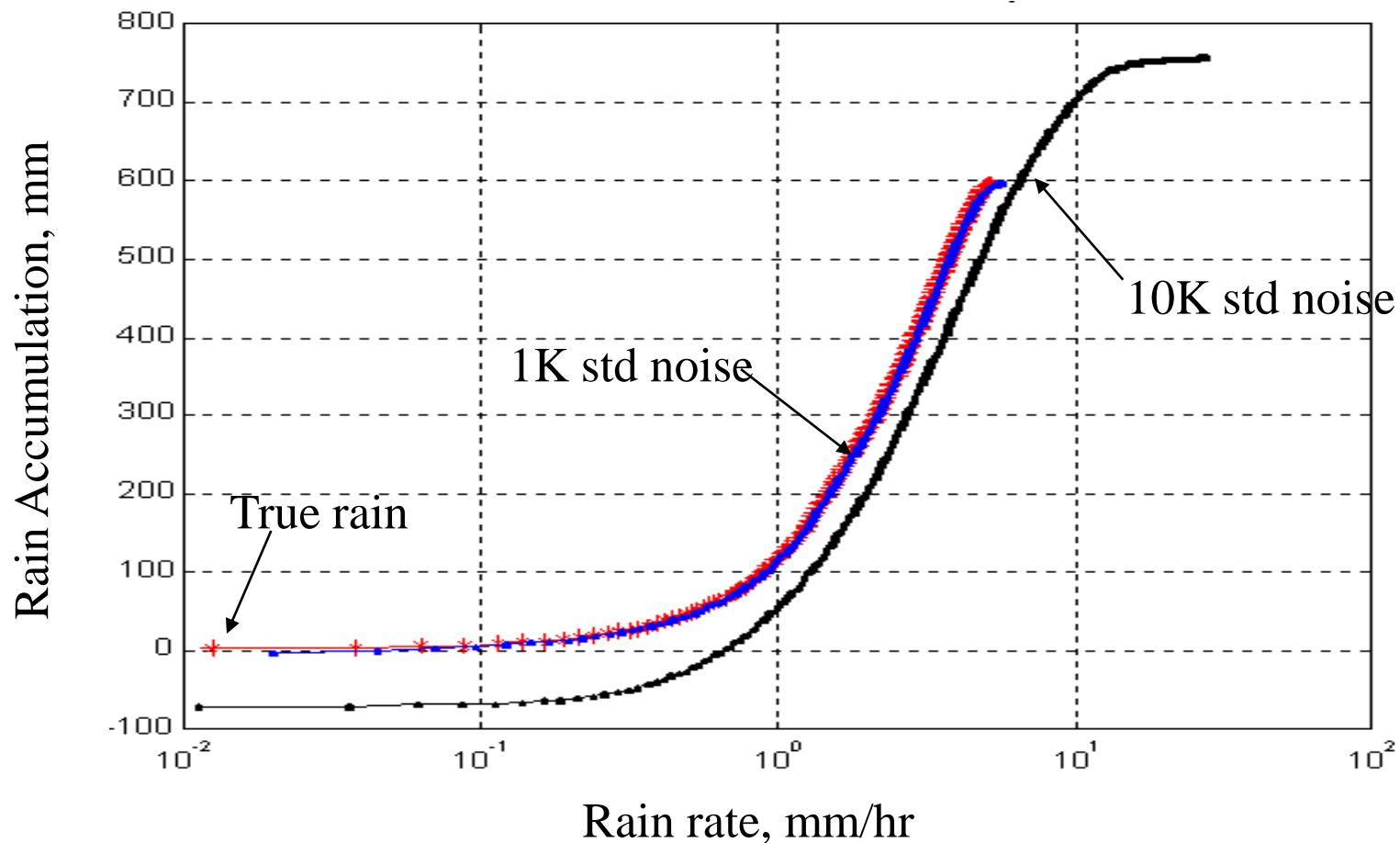


# Rain Rate pdf





# Rain cdf



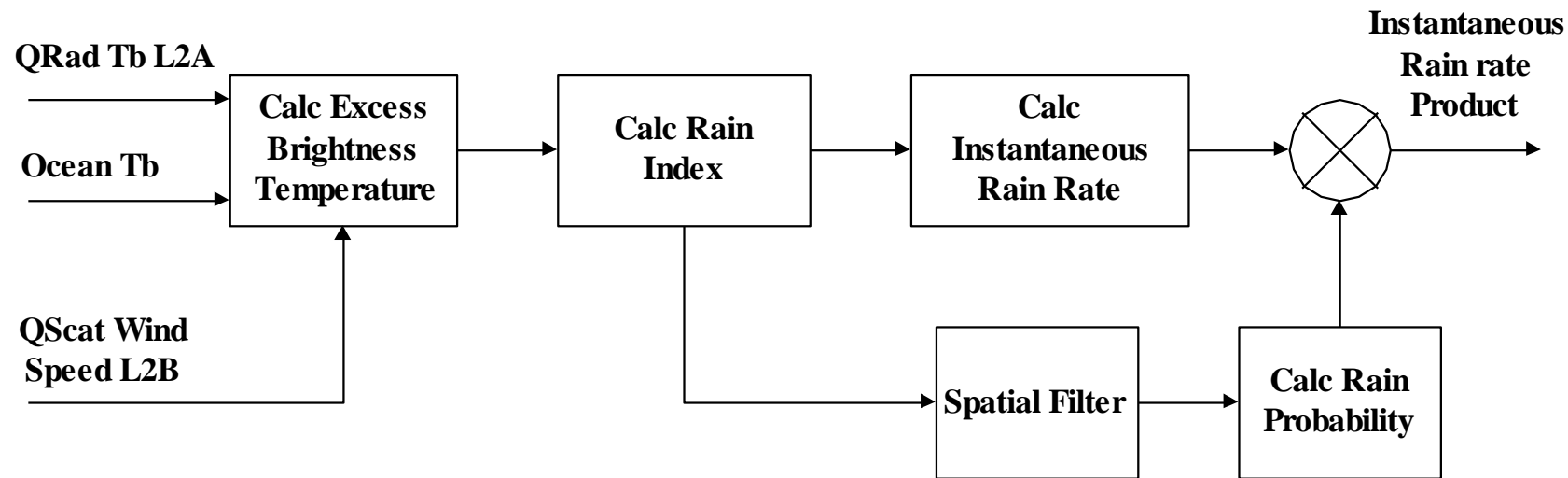


# Rain Rate Algorithm

- **Instantaneous Rain Rate**
  - Global Average



# Instantaneous Rain Rate Algorithm



$$RI_p = \frac{\Delta Tb_p - \Delta T_{0p}}{\sigma_p / \sqrt{\# pulses}}$$

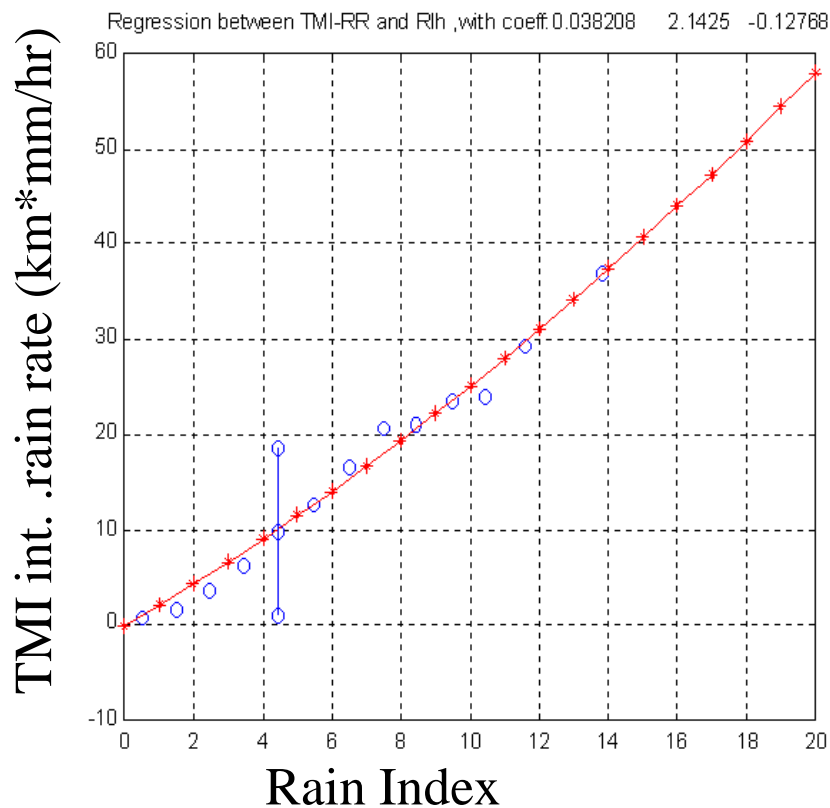
Where:

- $\Delta Tb$  = “excess Tb”, K;
- $\Delta T_0$  = offset based upon a linear regression between TMI integrated rain rate and  $\Delta Tb$ , K;
- $\sigma$  = the QRad measurement standard deviation
- $p$  = polarization.
- $\# pulses$  = the number of pulses averaged

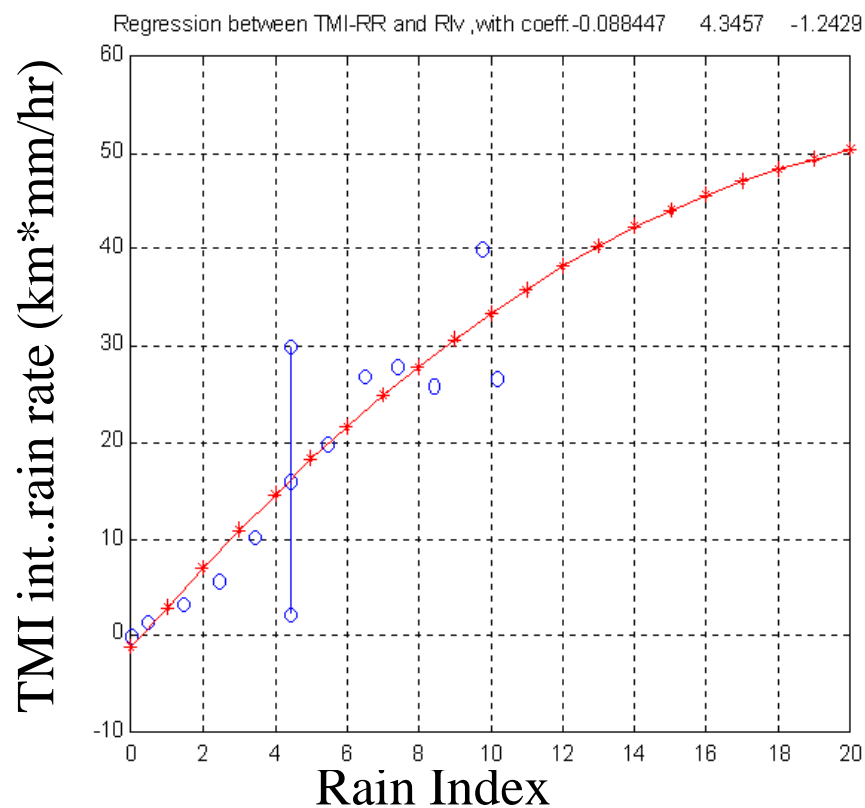


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# TMI Integrated Rain Rate – Qrad Rain Index Relationship



(a) H-pol

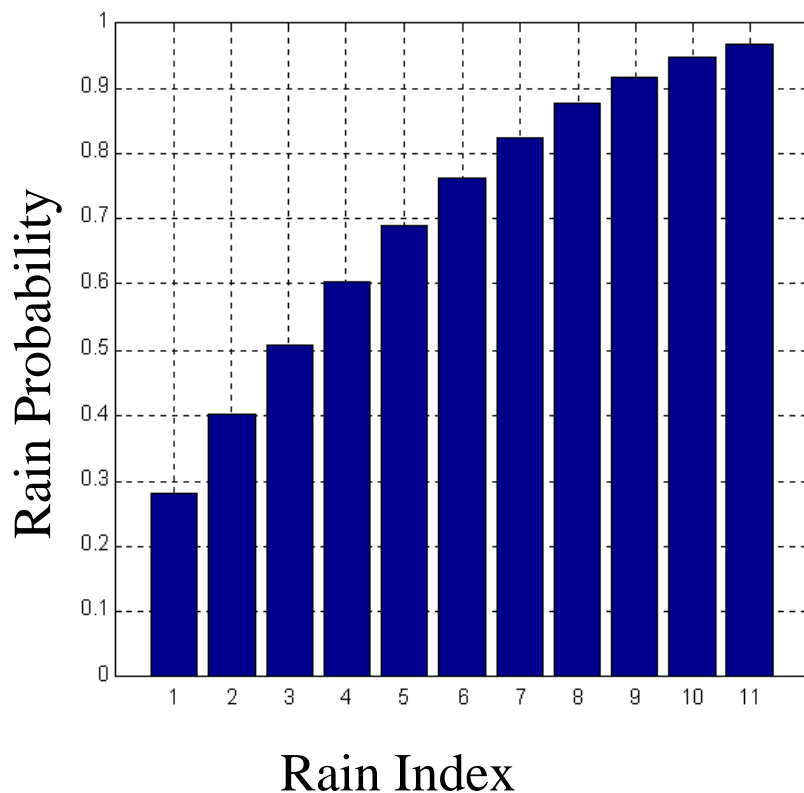


(b) V-pol

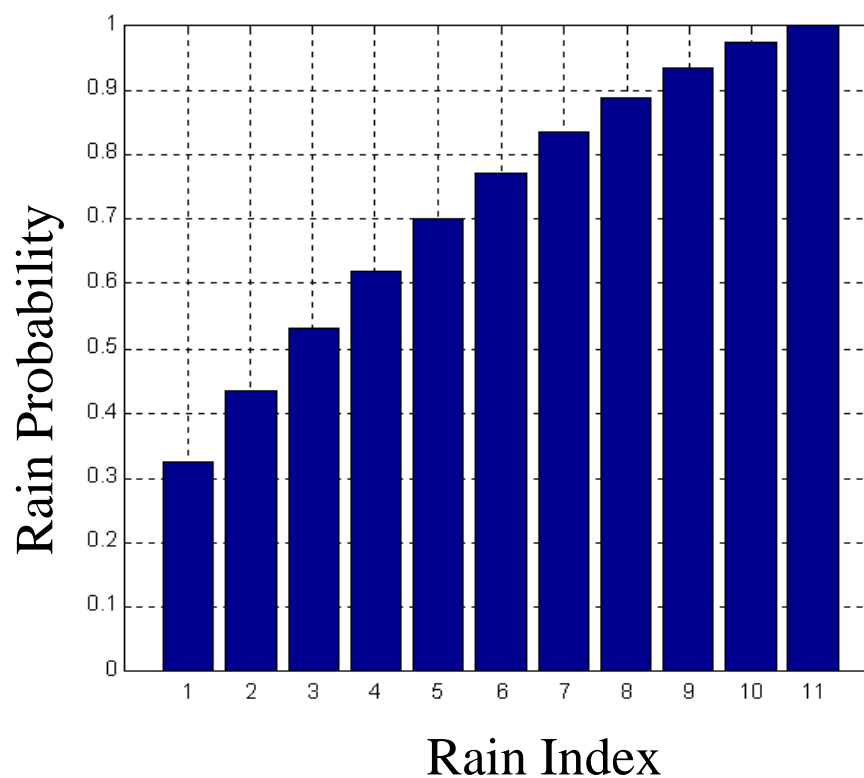


# Rain Index Probability

H-pol



V-pol





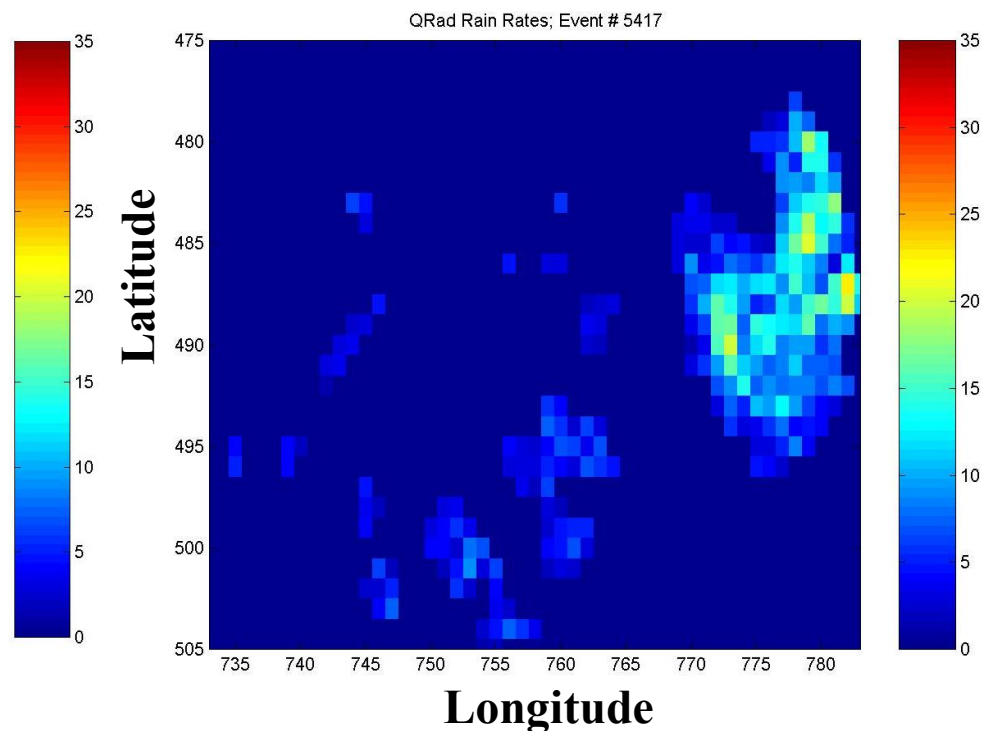
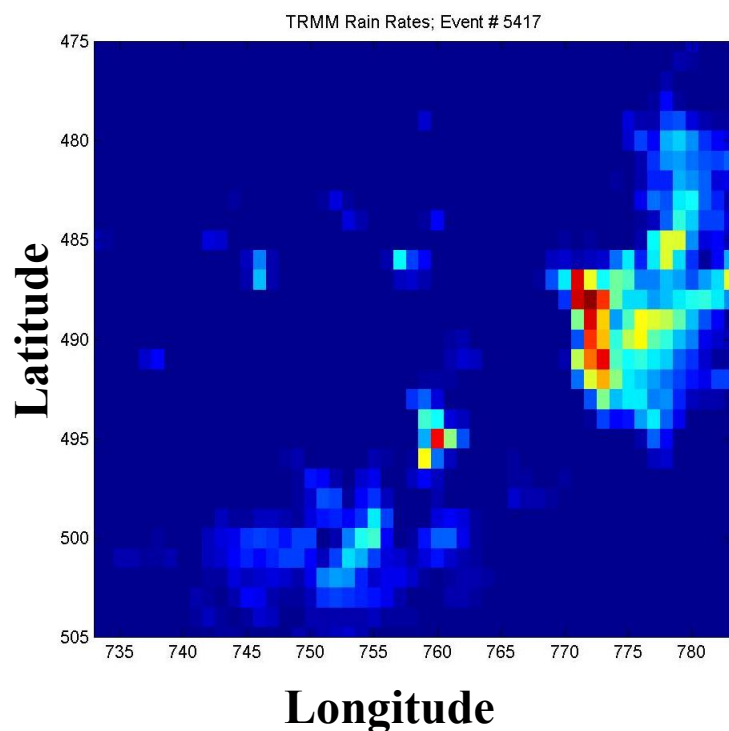
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# Instantaneous Rain Rates Comparison

(km\*mm/hr)

TMI

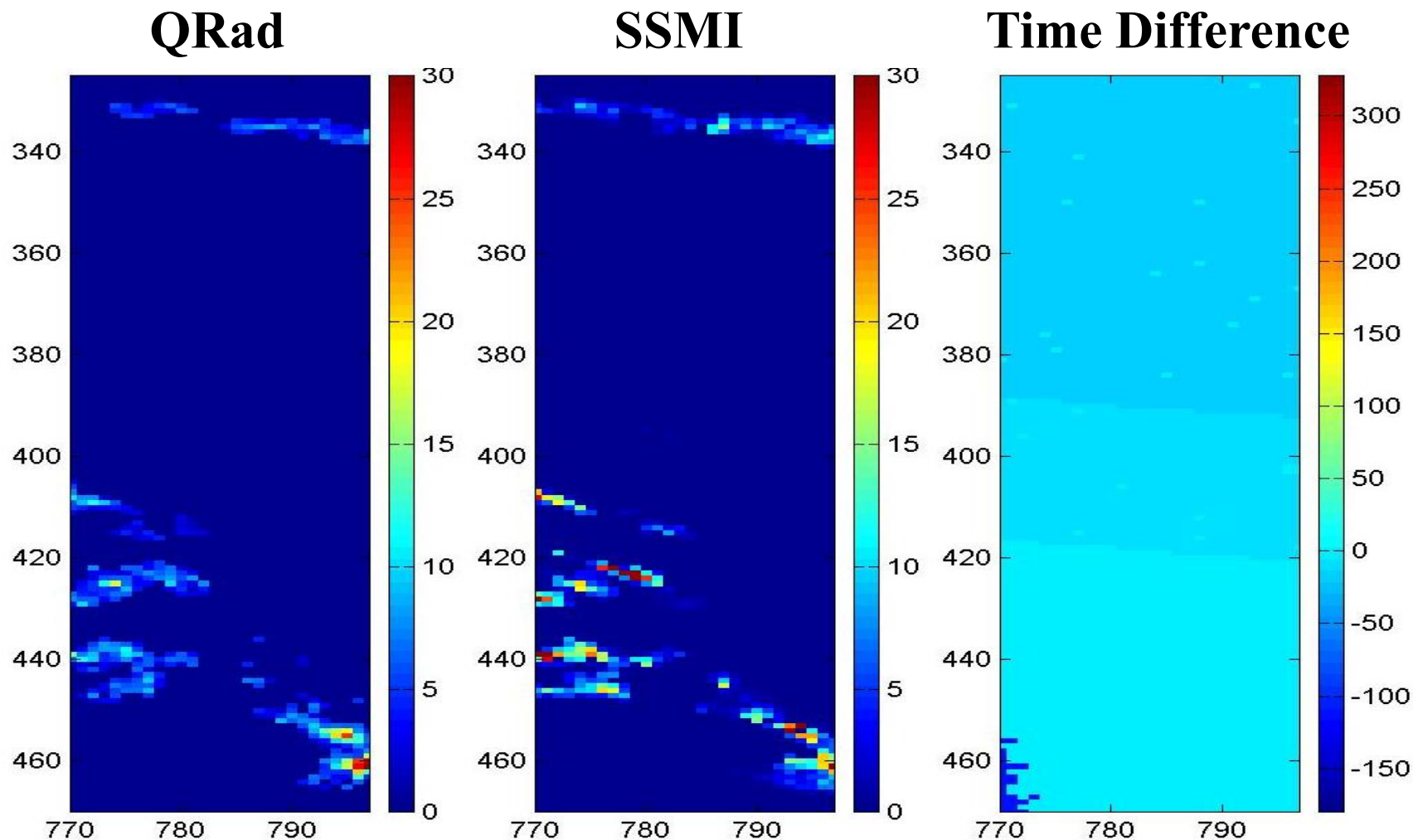
QRad





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# Instantaneous Rain Rates Comparison





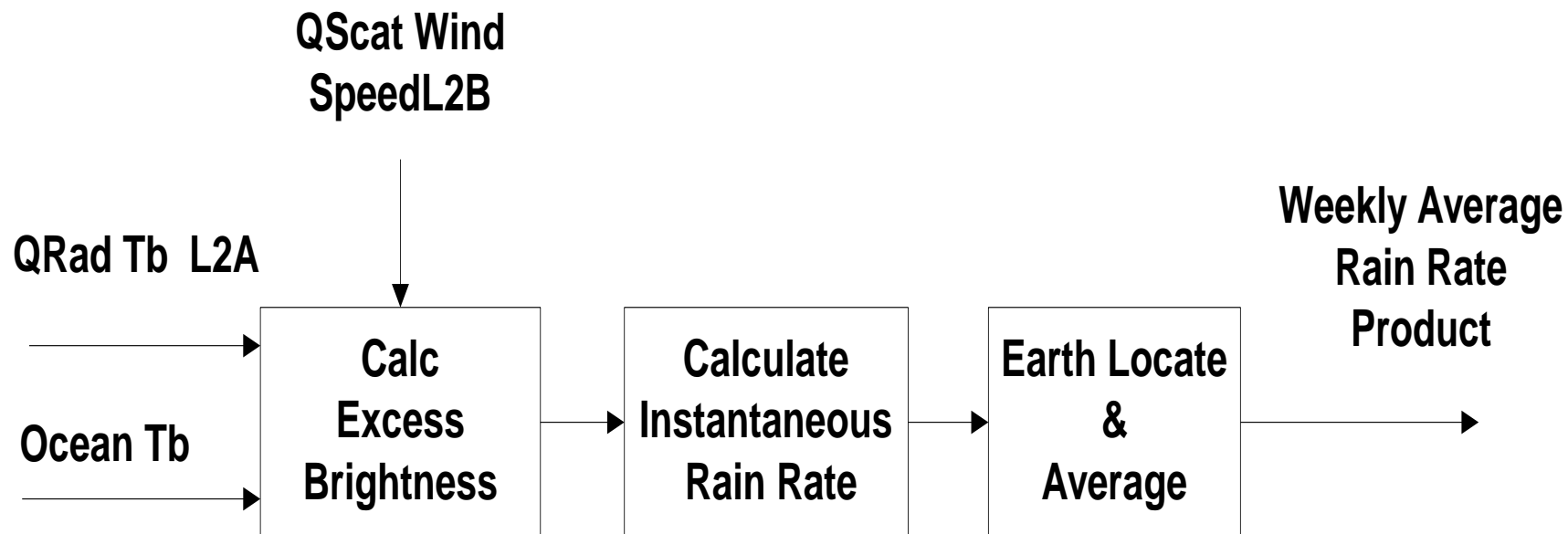
# Rain Rate Algorithm

- Instantaneous Rain Rate
  - **Global Average**



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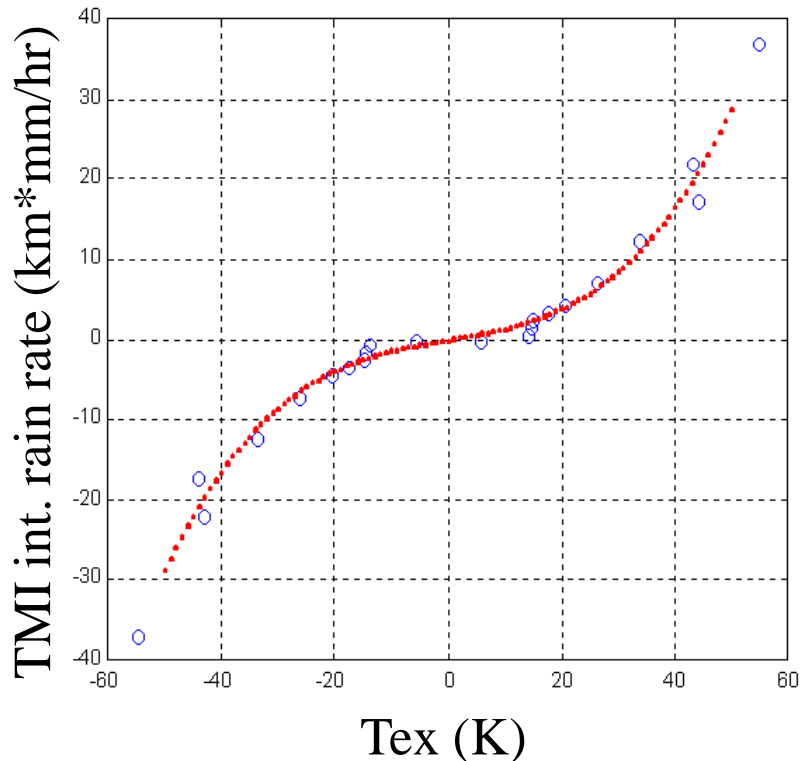
# Global Avg Rain Rate Algorithm



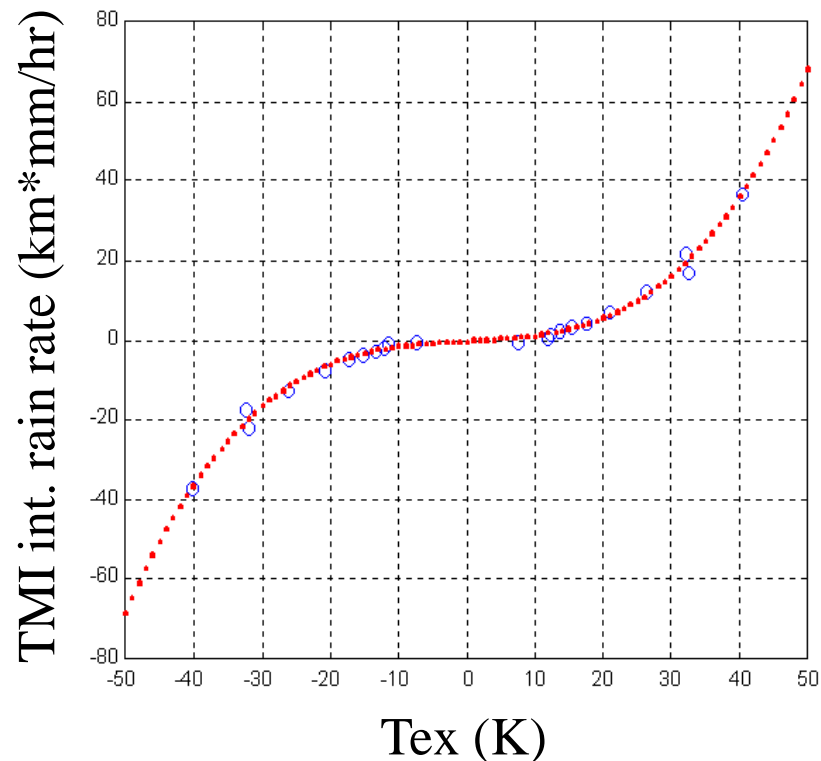


# TMI Integrated Rain Rate – Qrad Tex Relationship

(a) H-pol



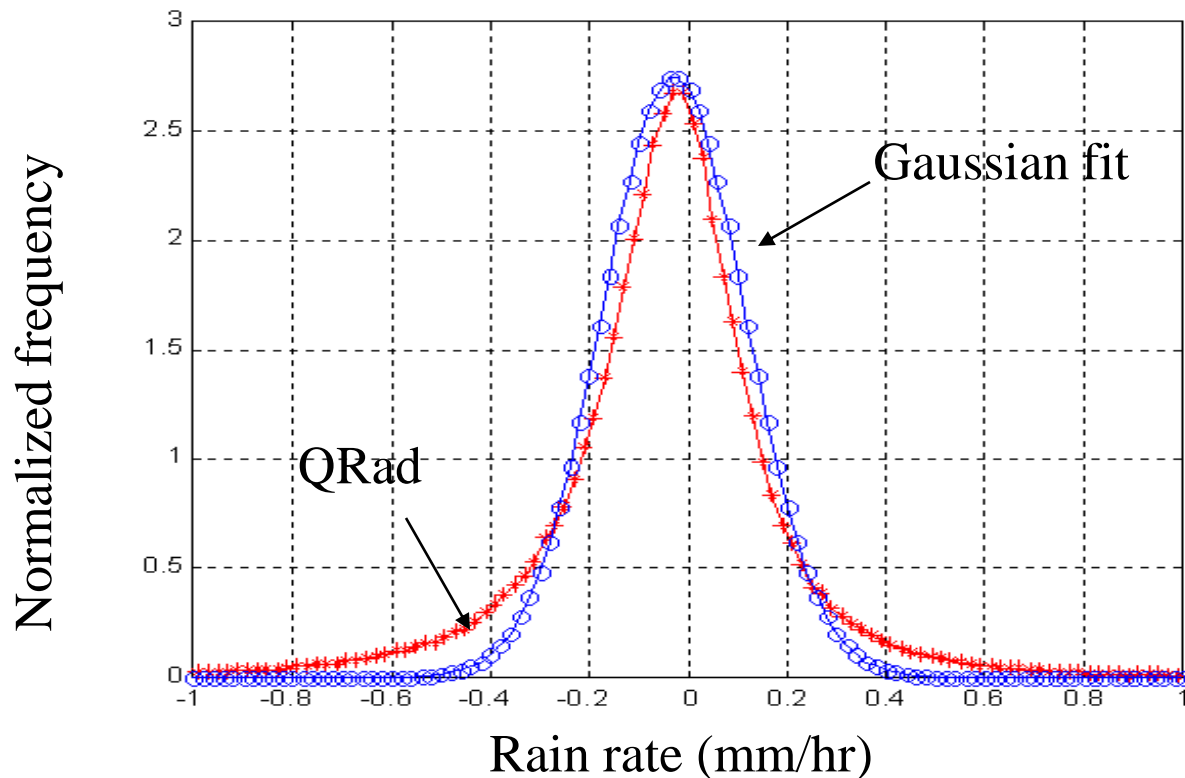
(b) V-pol





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# Rain Rate pdf - 800 Rain-free $5^\circ \times 5^\circ$ Areas

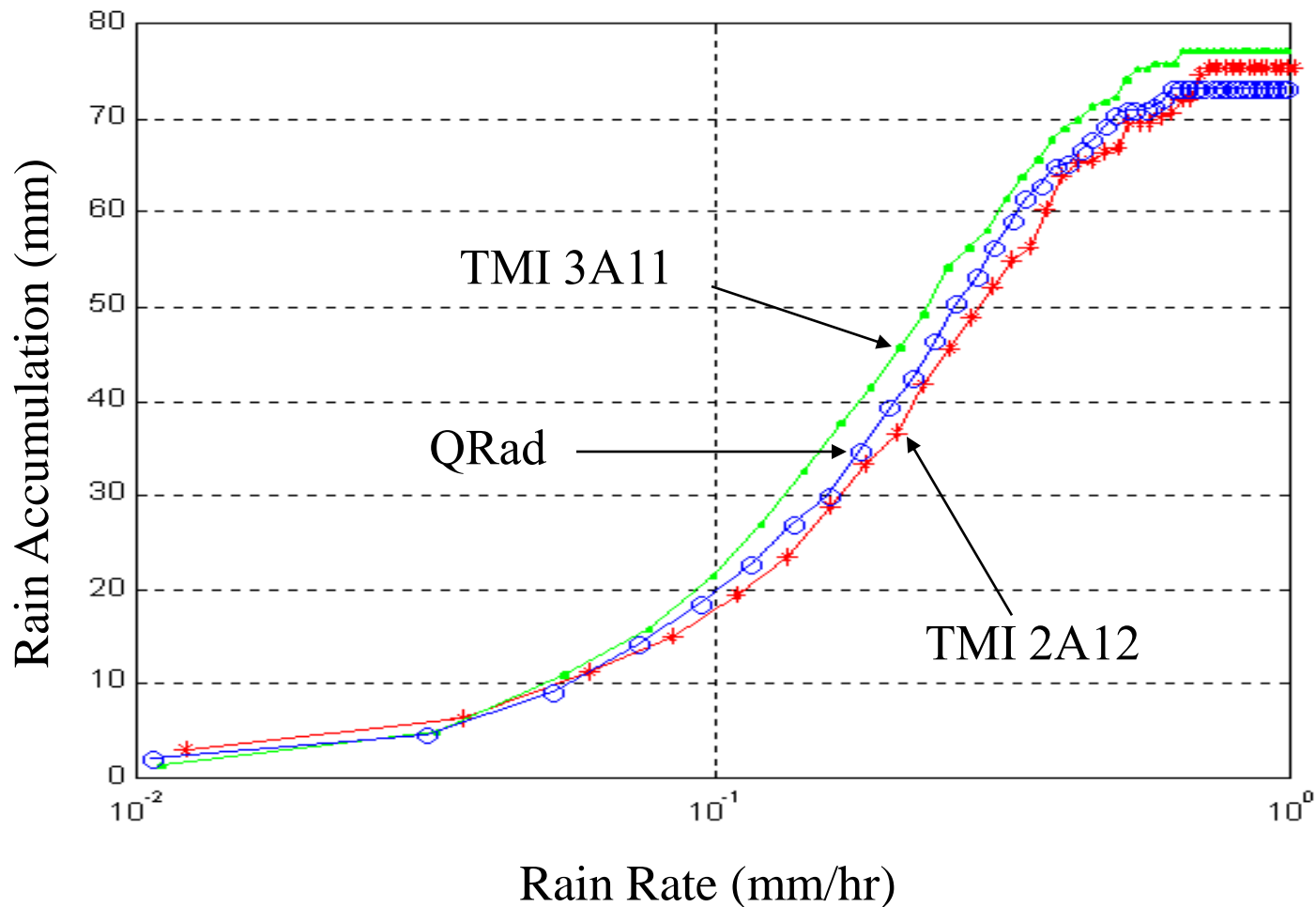


Mean = - 0.030 and std = 0.145



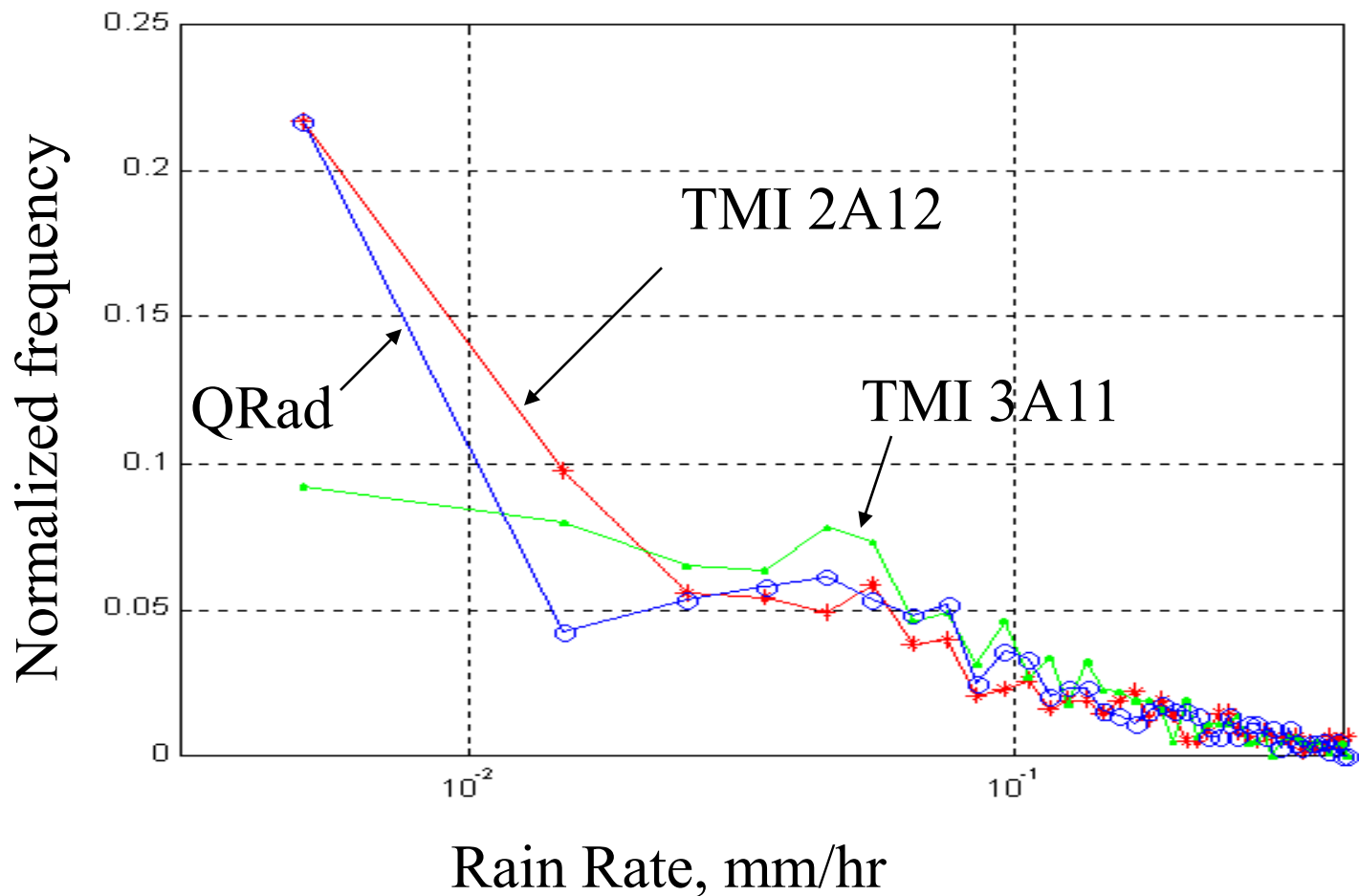
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# Monthly Average Global Rain Accumulations





# Monthly Average Rain Rates





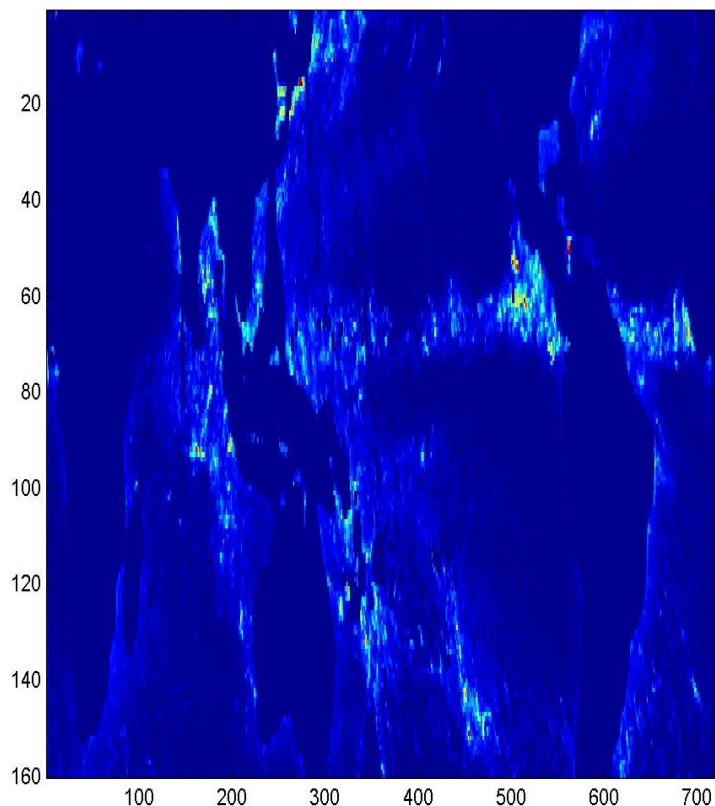
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# Monthly Avg Rain Rates (Jun. 2000 - $0.5^\circ \times 0.5^\circ$ )

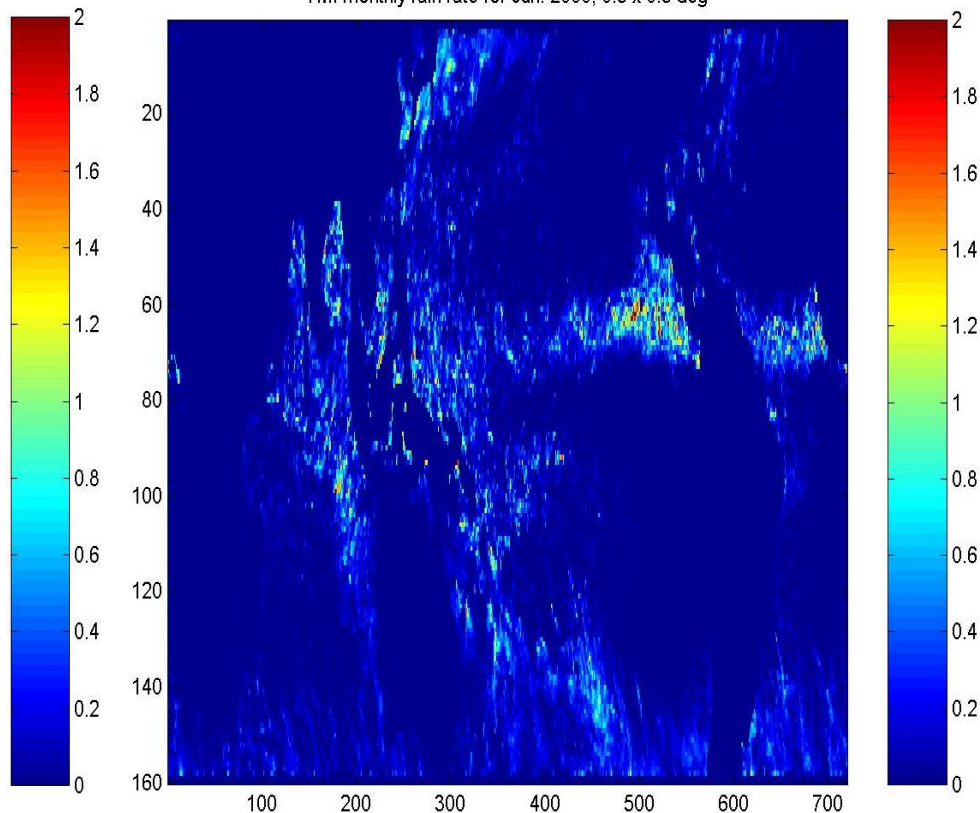
QRad

TMI

QRad monthly rain rate for Jun. 2000,  $0.5 \times 0.5$  deg



TMI monthly rain rate for Jun. 2000,  $0.5 \times 0.5$  deg

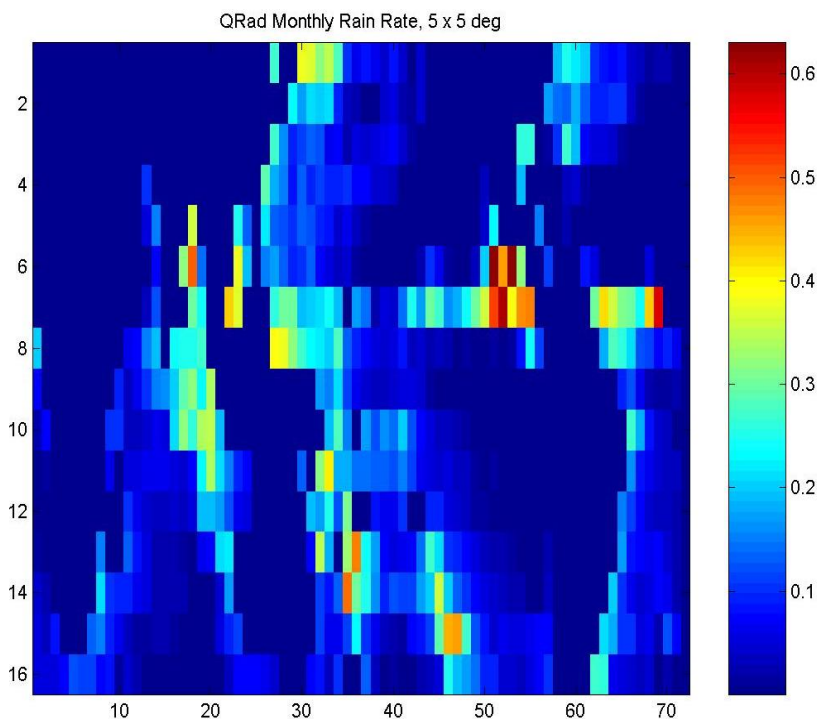




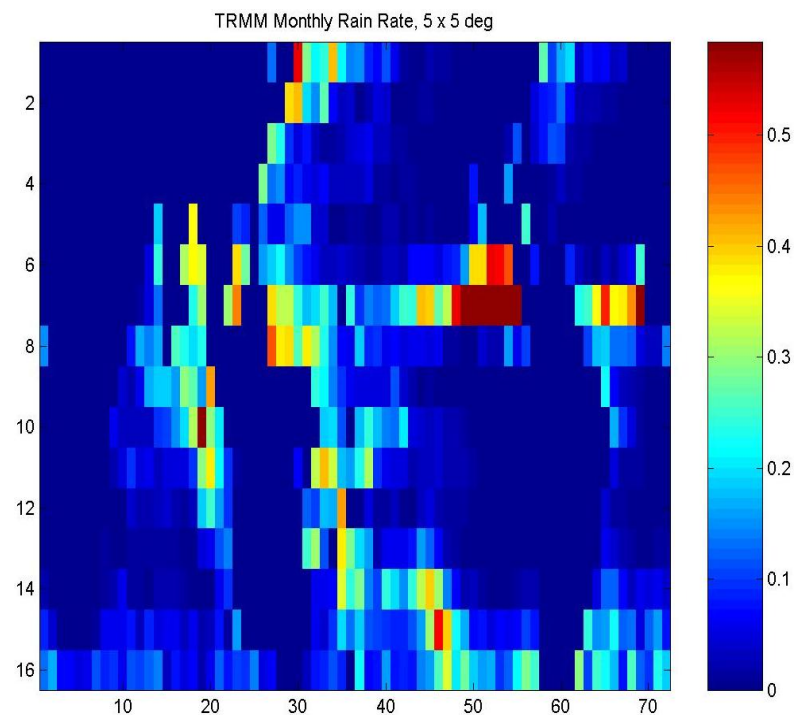
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# Monthly Avg Rain Rates (Jun. 2000 - 5° x 5° )

## QRad



## TMI





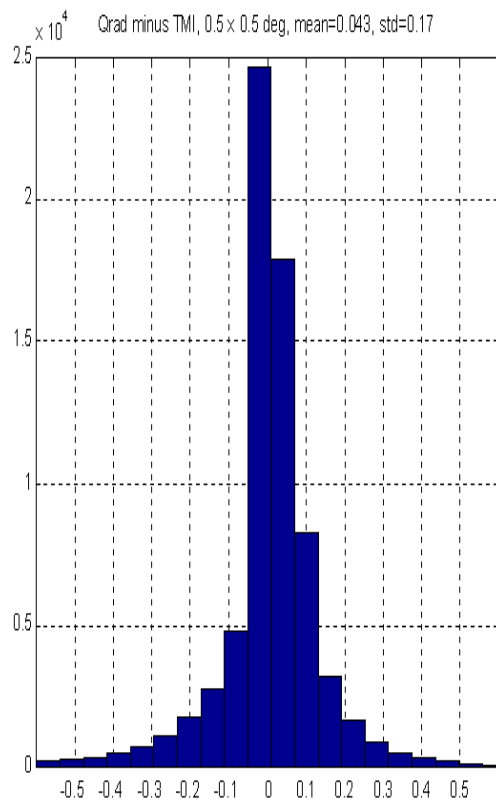
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# QRad minus TMI Mo. Avg Rain Rates

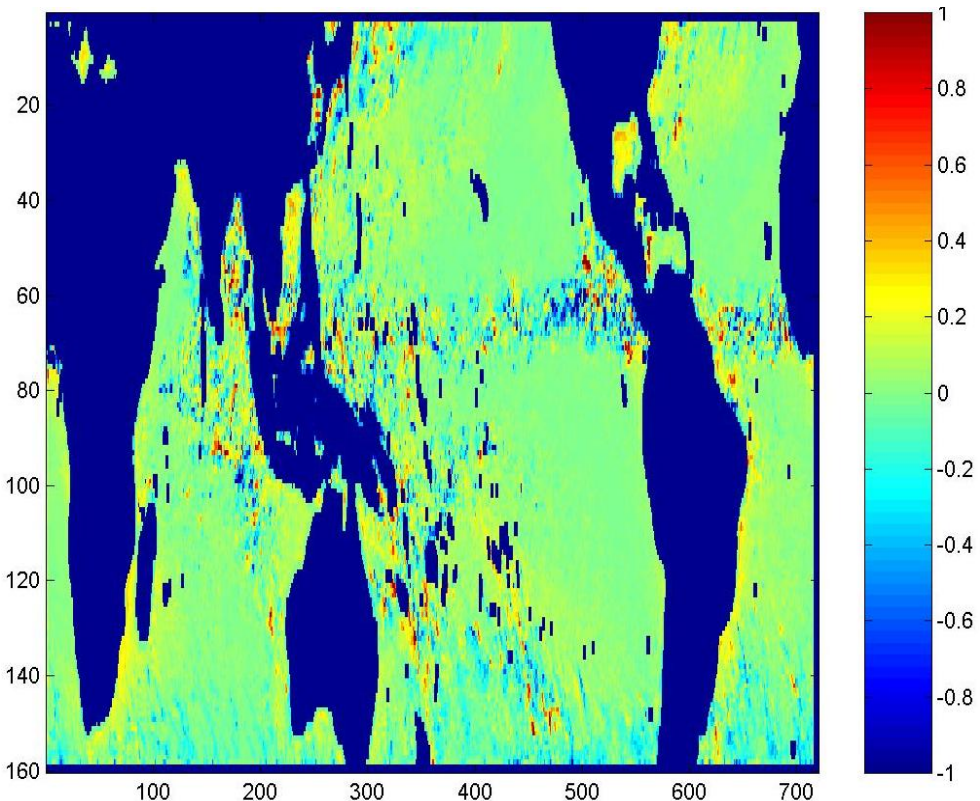
( $0.5^\circ \times 0.5^\circ$ )

Mean = 0.04

Std = 0.17



Delta-RR



Delta-Rain Rate , mm/hr



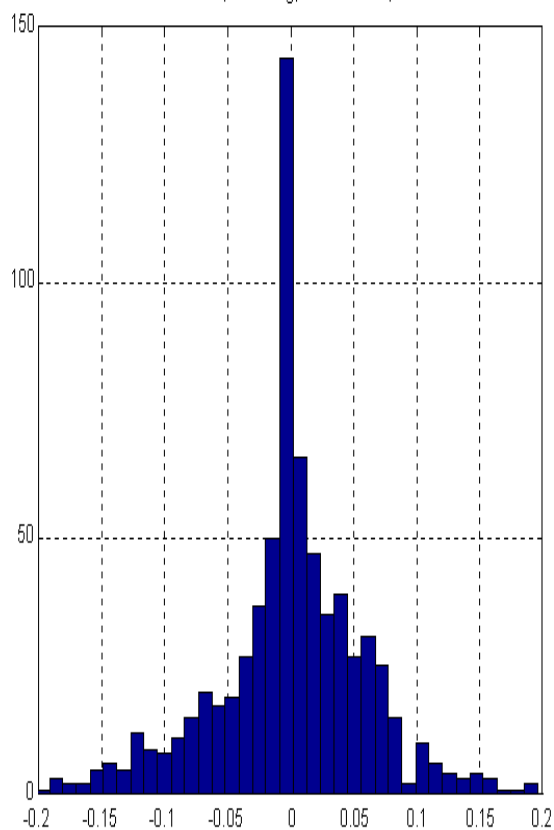
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# QRad minus TMI Mo. Avg Rain Rates ( $5^\circ \times 5^\circ$ )

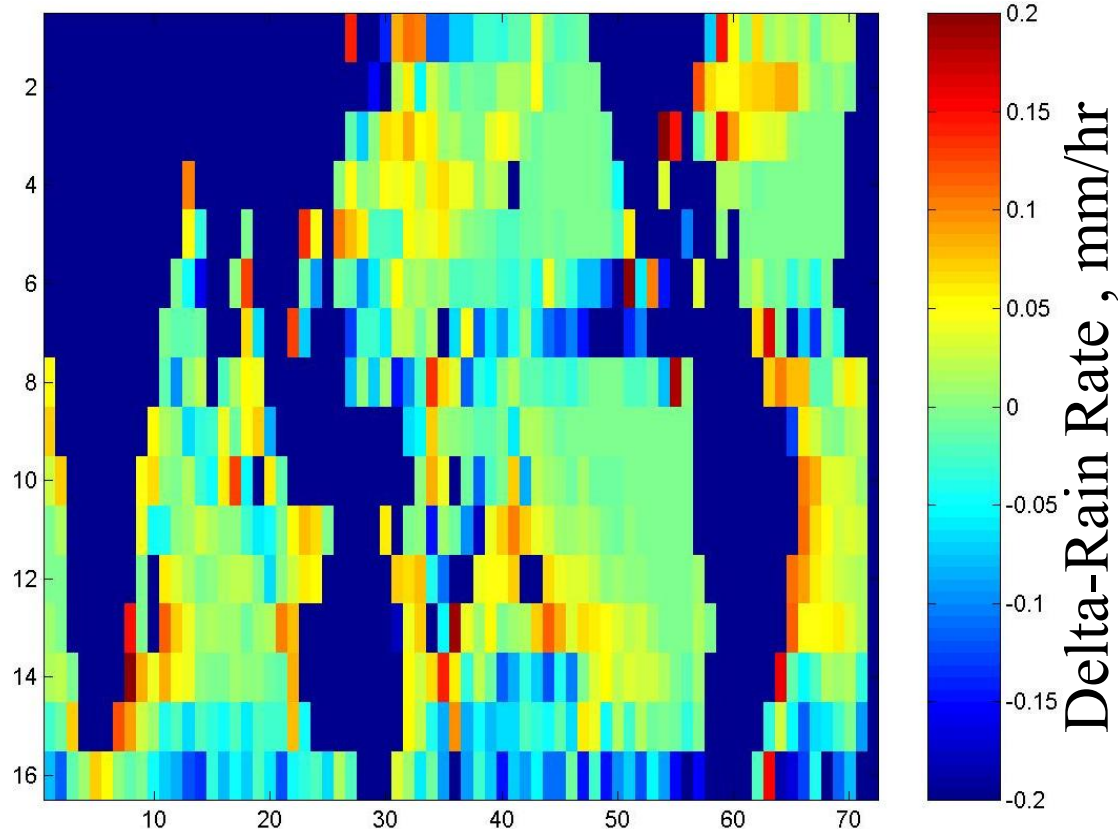
Mean = 0.002

Std = 0.024

Qrad minus TMI, 5 x 5 deg, mean=0.002, std=0.024

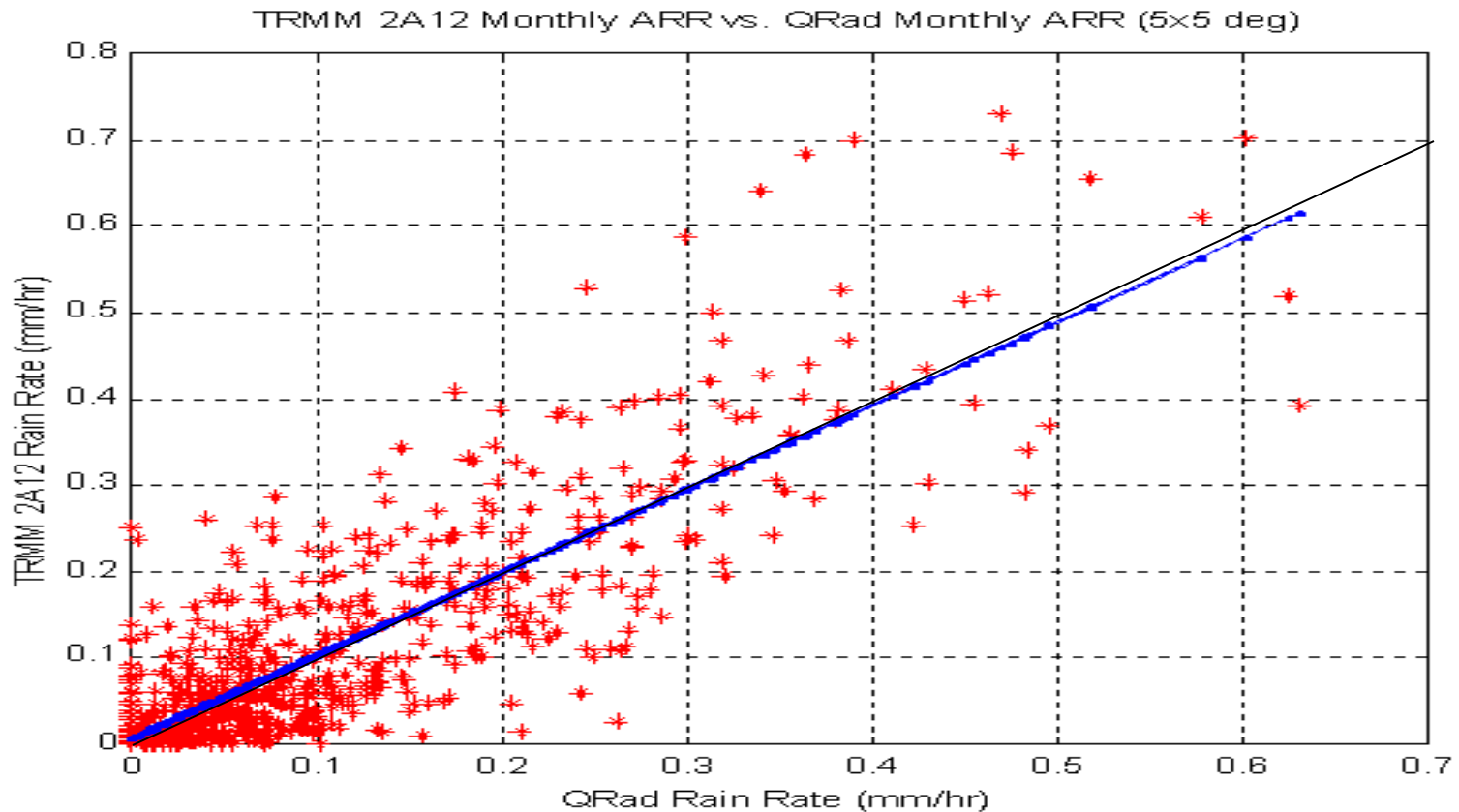


Delta-RR





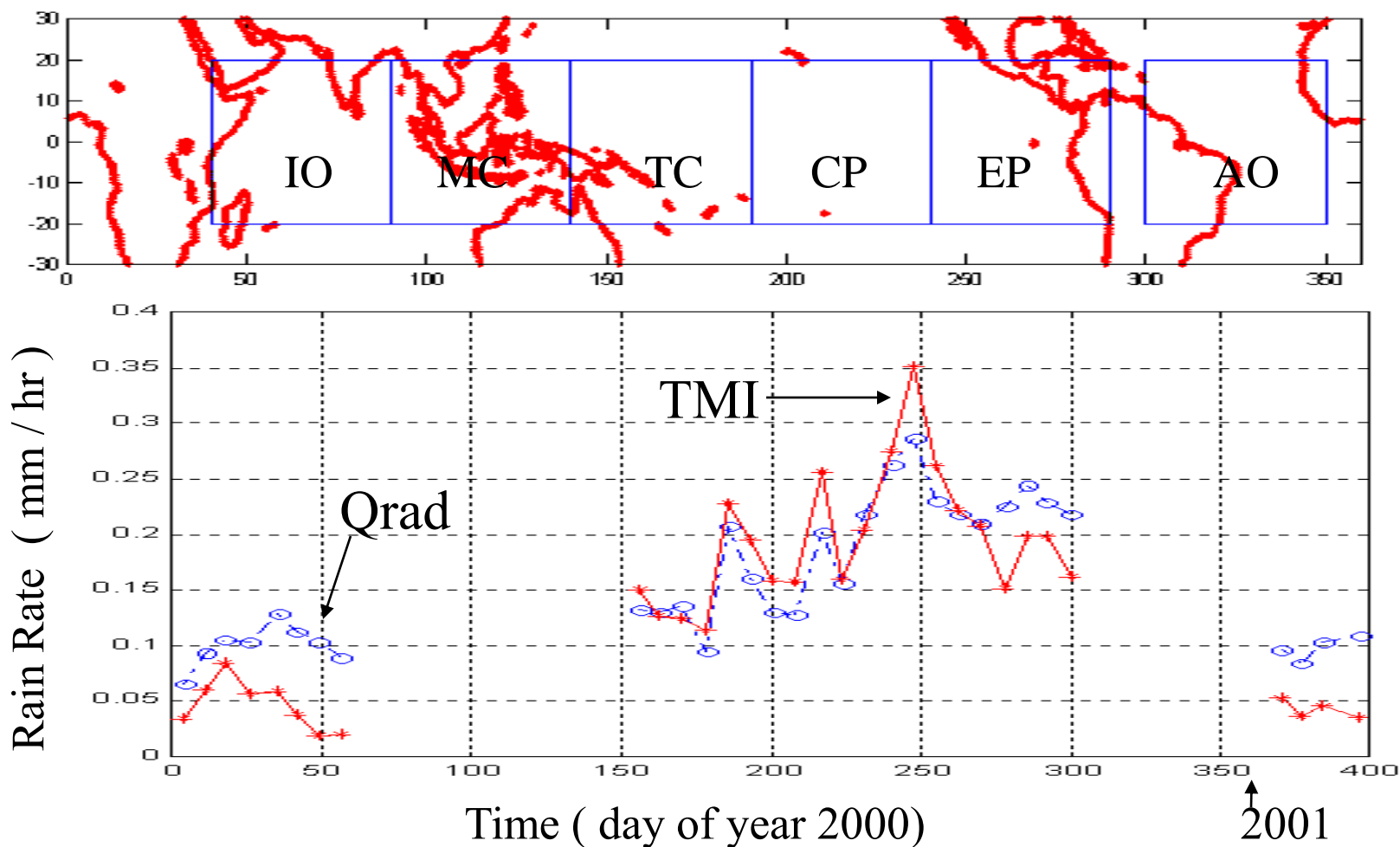
# Rain Rate Scatter Diagram TMI vs. Qrad (5° x 5° )





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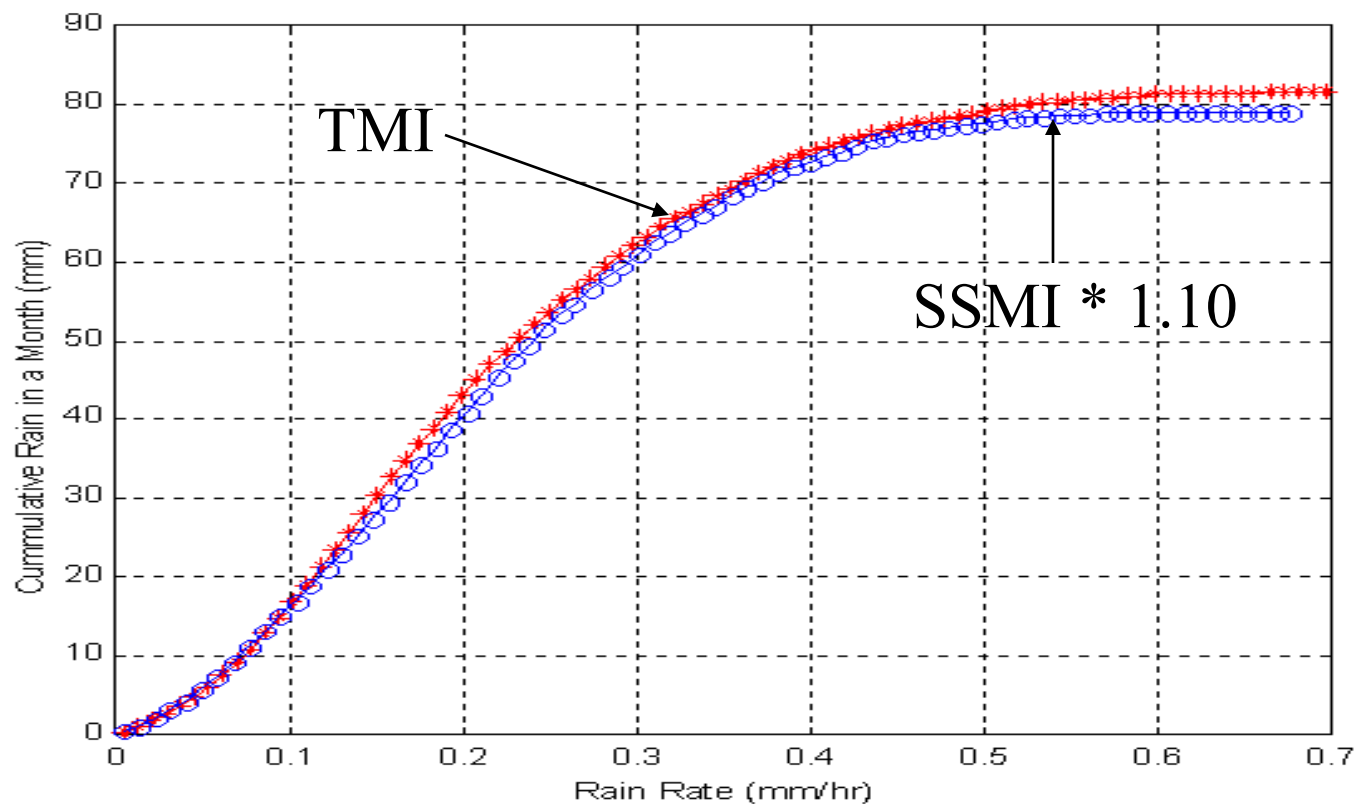
# Weekly Zonal Avg Rain Rate for 20° N - 10° N





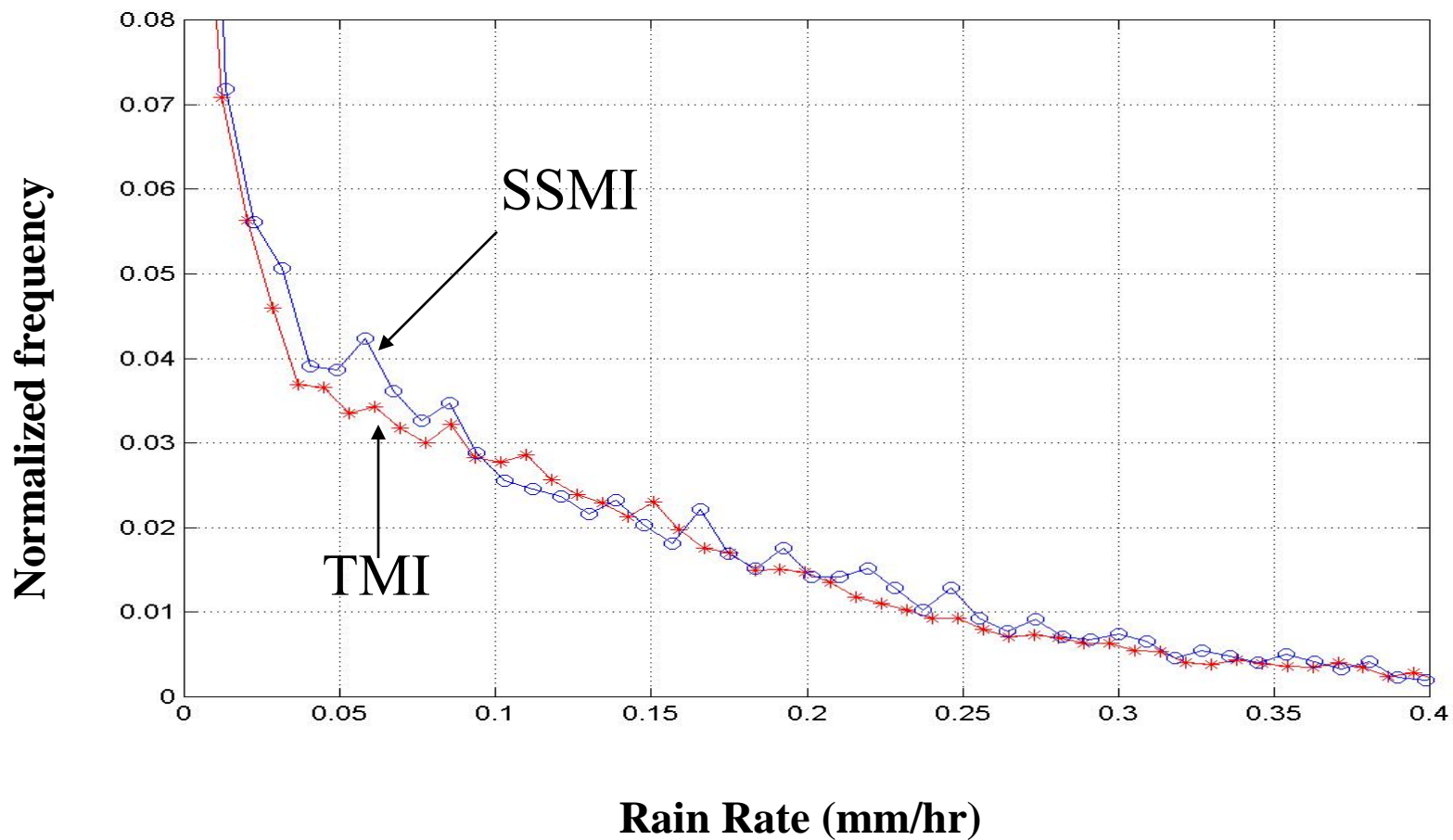
# SSMI Rain Rate Adjustment

## Monthly Average Global Rain Accumulations





# Monthly Avg. Rain Rate

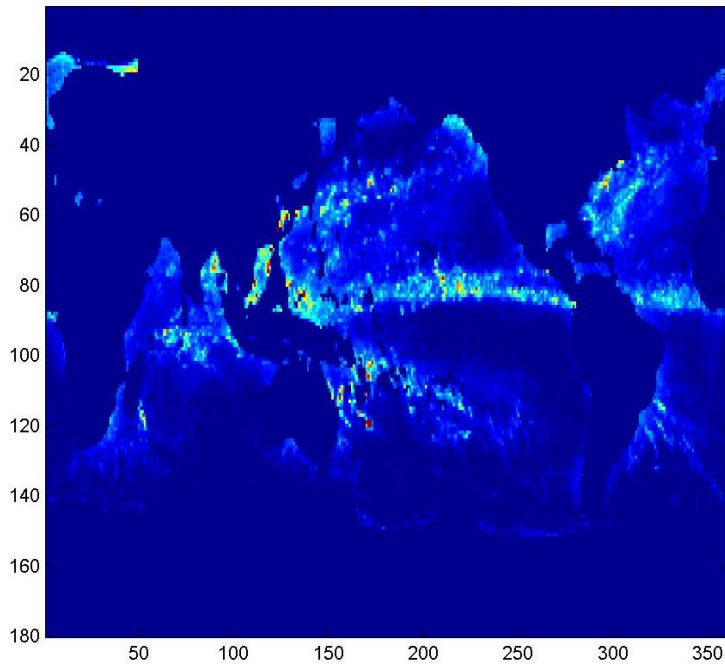




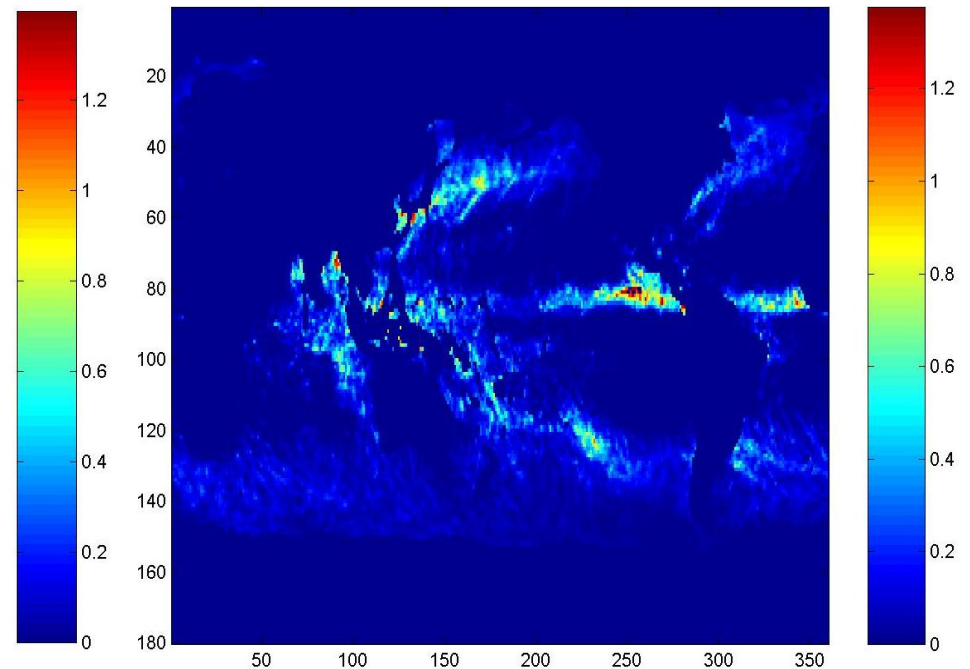
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# Mon. Avg. Global Rain Rates for Qrad and SSMI, $1^\circ \times 1^\circ$

QRad



SSMI



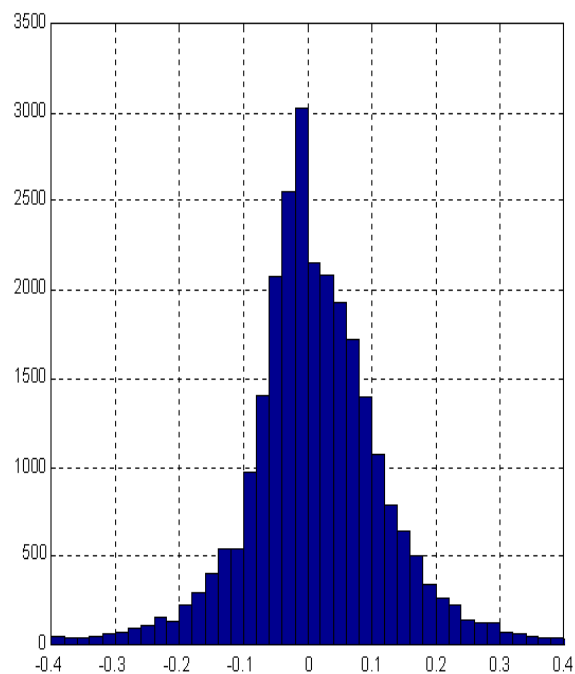


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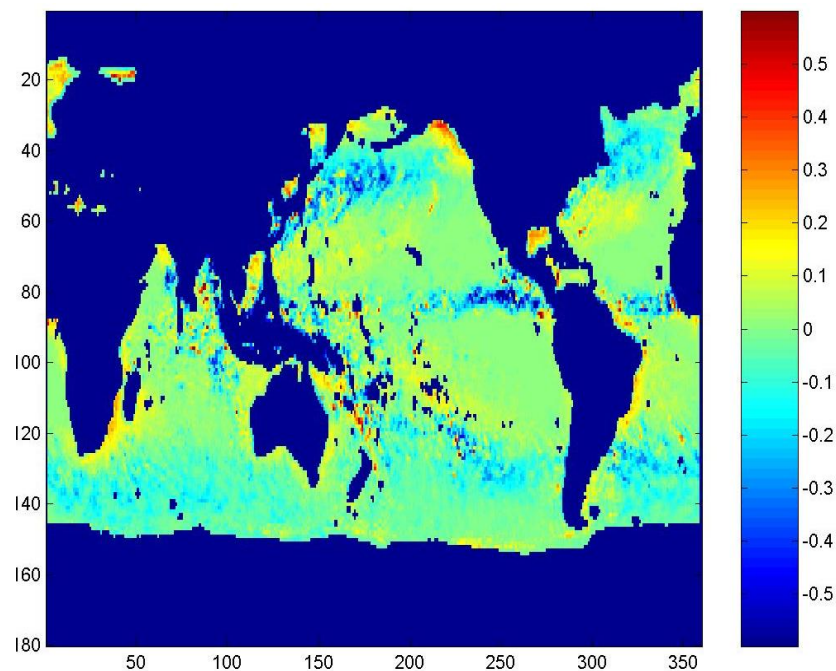
# QRad minus SSM/I global Mo. Avg Rain Rates ( $1^\circ \times 1^\circ$ )

Mean = 0.002

Std = 0.024



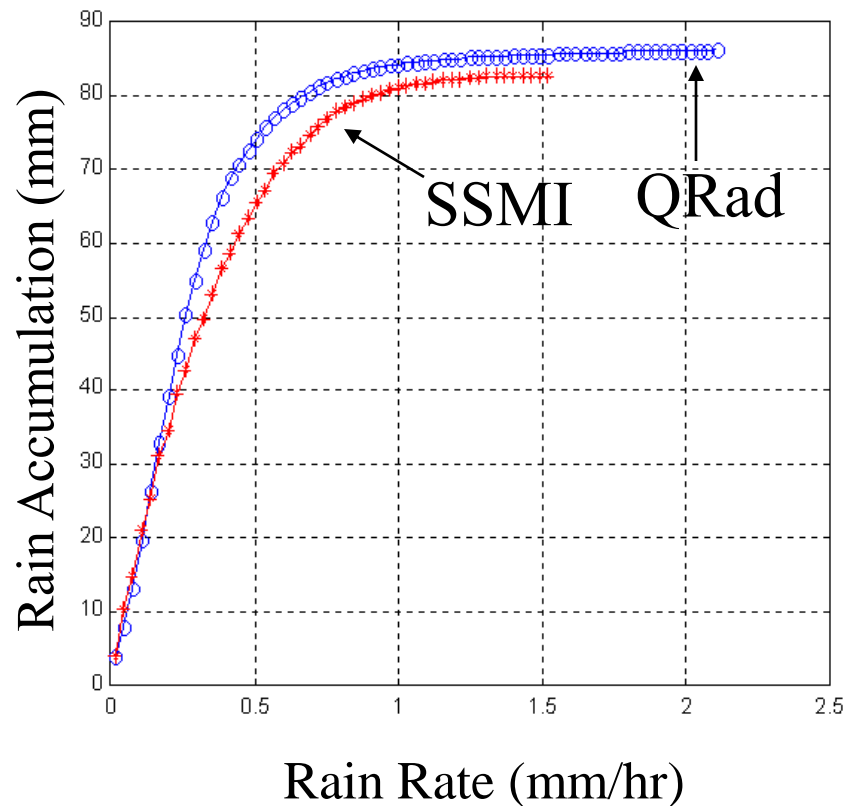
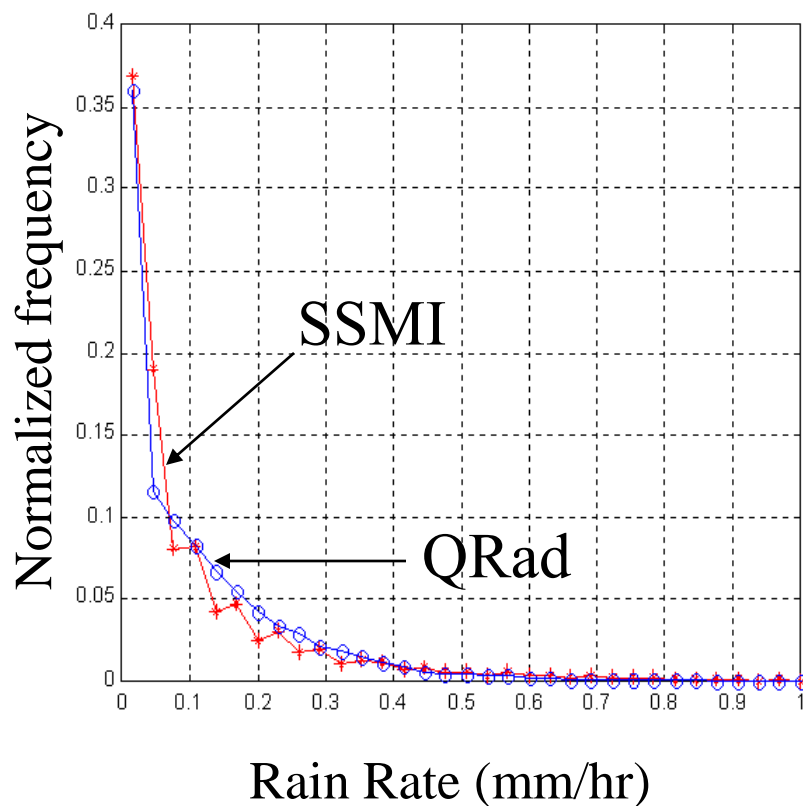
Delta-RR



Delta-Rain Rate (mm/hr)



# QRad and SSMI Monthly Global Rain Rates





# Conclusions

Based upon my thesis:

- QRad provides quantitative estimates of instantaneous rain rate over oceans
  - JPL has implemented this algorithm in science data processing
  - Good comparisons of instantaneous rain rate with TMI and SSMI when collocation times are  $\pm 1$  hr



## Conclusions – cont.

Based upon my thesis:

- QRad provides quantitative estimates of global average rain rate over oceans
  - Weekly to monthly time scales
  - Monthly average comparisons with TMI and SSMI rain rates are good
    - QRad underestimates high rain rates and slightly over estimates low rain rates
    - Differences in over pass times may influence the weekly to monthly averages



# Publication

- **Wang, Y., Jones, W. L., Park, J. and J. Zec, " Quantitative Rain Rate Estimates over Oceans using QuikSCAT," Oceanology Americas 2001, NASA Oceanography Scientific Conference, April 3-4, 2001, Miami, FL.**
- **Jones, W. L., Kasparis, T., Wang, Y. and J. Park, "Global Ocean Rain Rates from QuikSCAT," 7th International Conference on Precipitation, June 30 -July 3, 2001, Samoset Resort, Rockport, ME.**
- **Susanj, Mladen, Jones, W. L., Wang, Y., Zec J., and Jun-Dong Park, "A Rain Flag over Oceans for the SeaWinds Scatterometer on QuikSCAT", AGU Spring meeting, May 30 - June 3, 2000, Wash DC**
- **Jones, W. L., Zec, J., Park, J. D. and Yanxia Wang, "Review of NSCAT Hurricane Research and Application to SeaWinds," SeaWinds Performance in Extreme Winds and Ambiguity Removal and Directional performance Workshop, Jet propulsion Lab, Aug. 29-30, 2000, Pasadena, CA**