An Algorithm for Measuring Rain over Oceans using the QuikSCAT Radiometer

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Overview

1. SeaWinds on QuikSCAT
2. Effect of Precipitation on Ocean T_b
3. Rain Algorithm Definition
4. Rain Algorithm Validation and Results
5. Conclusion

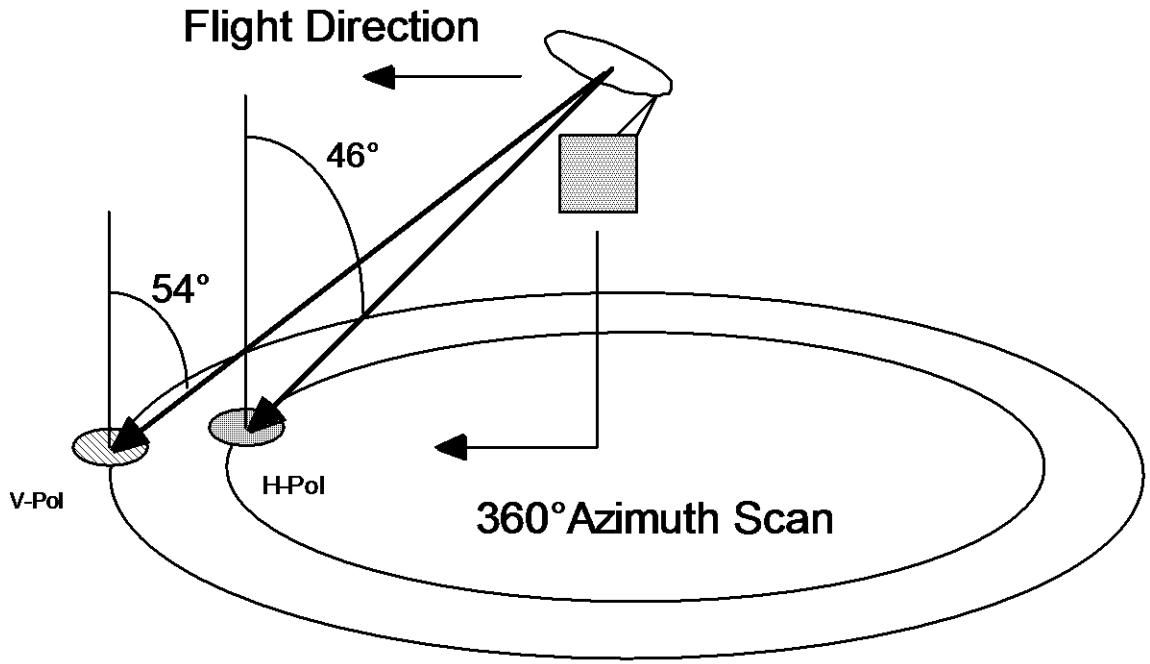
SeaWinds on QuikSCAT

- **Mission -** to provide continuous measurements of the Ocean surface winds.

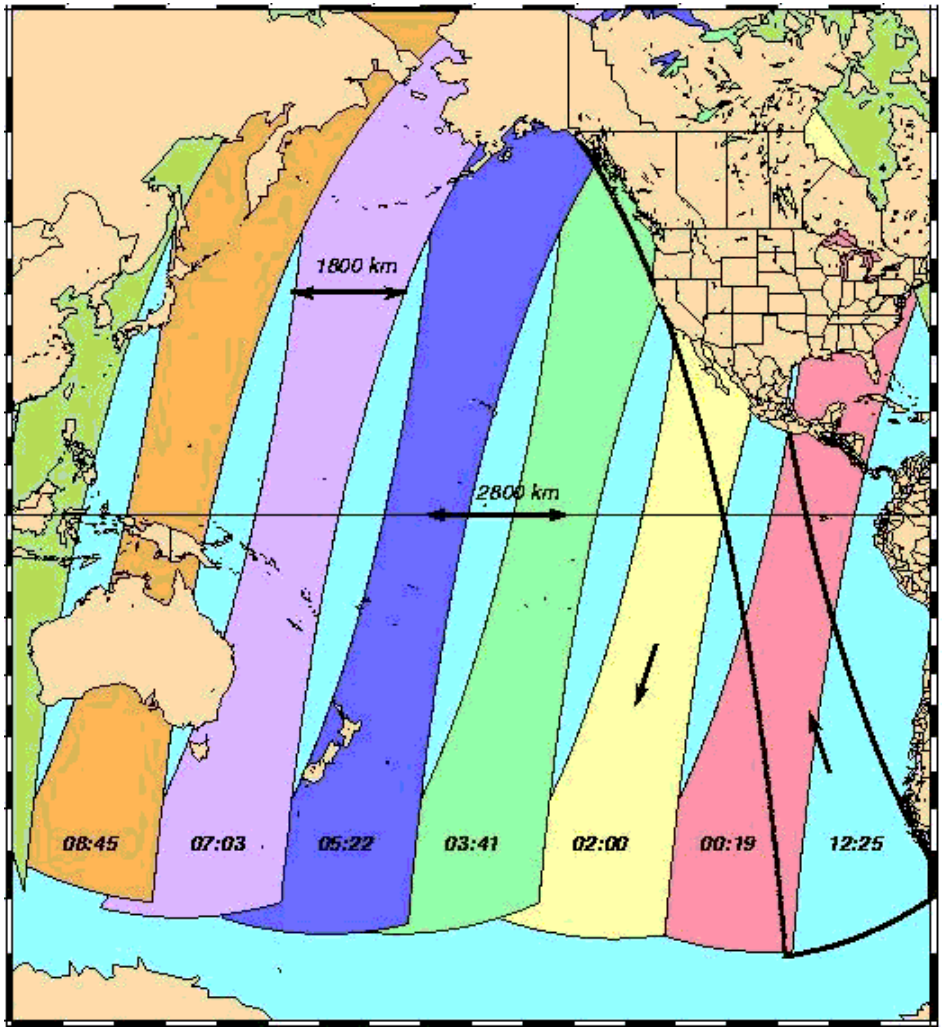
- **Problem -** Wind vector products occasionally degraded by the presence of rain.

- **Idea -** to develop the technique for identification of contaminated wv cells.

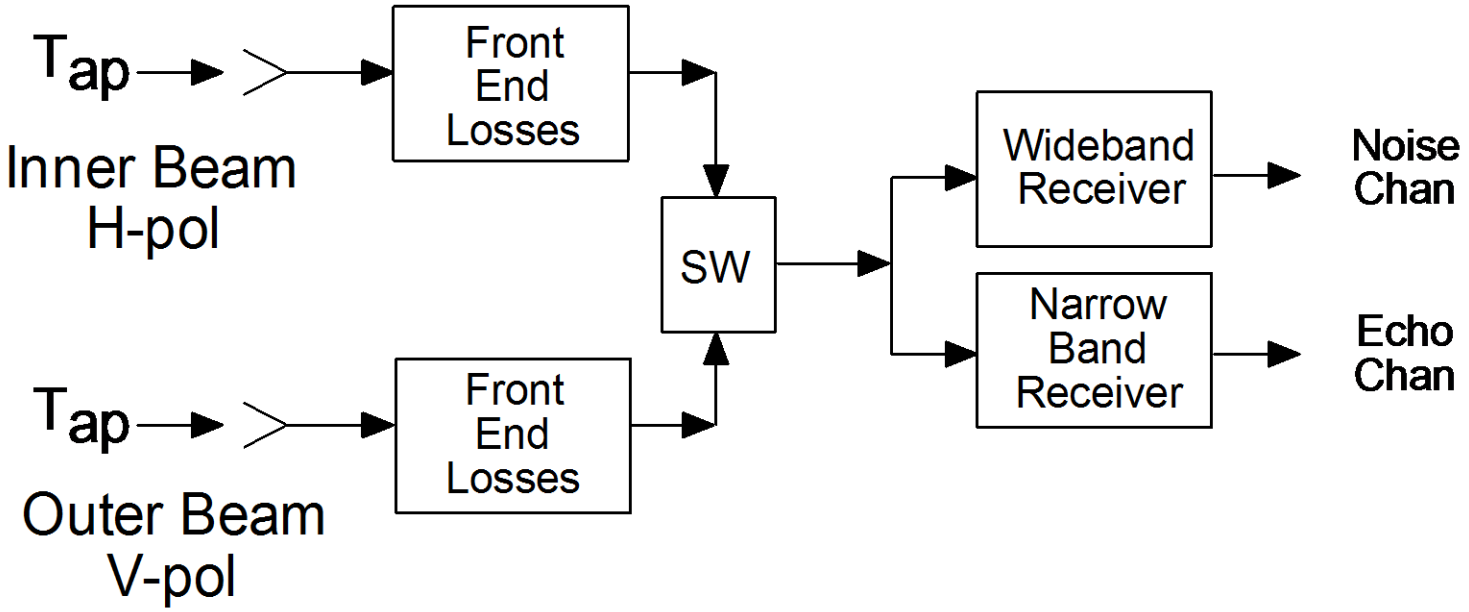
Geometry of the Sea Winds scatterometer on QuikSCAT



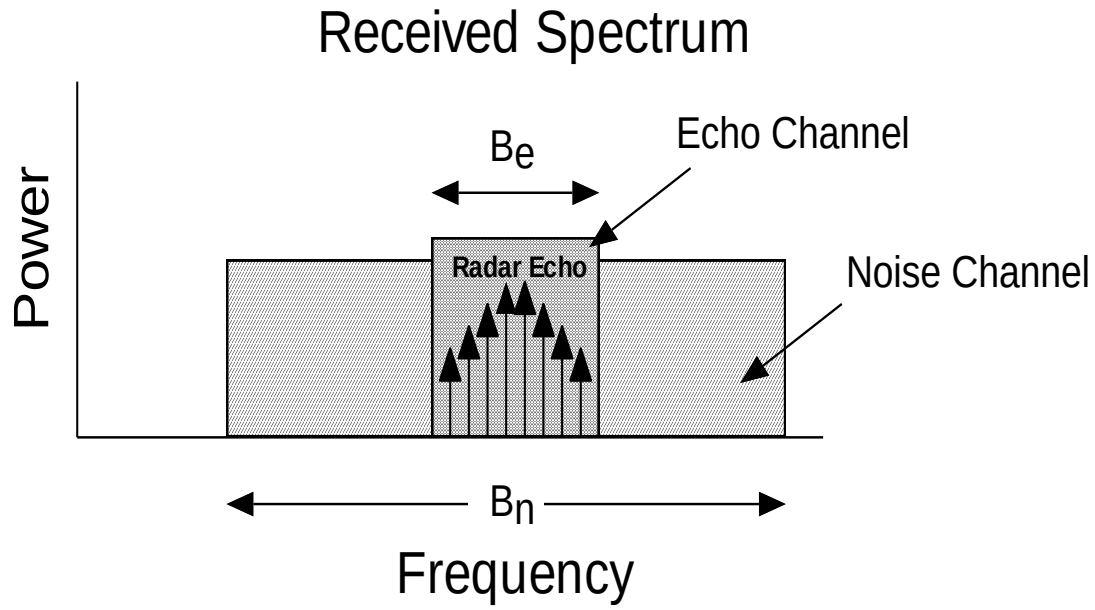
QuikSCAT swath projection



QuikSCAT Radiometer's (QRad) simplified block diagram



QuikSCAT Radiometer receiver spectrum

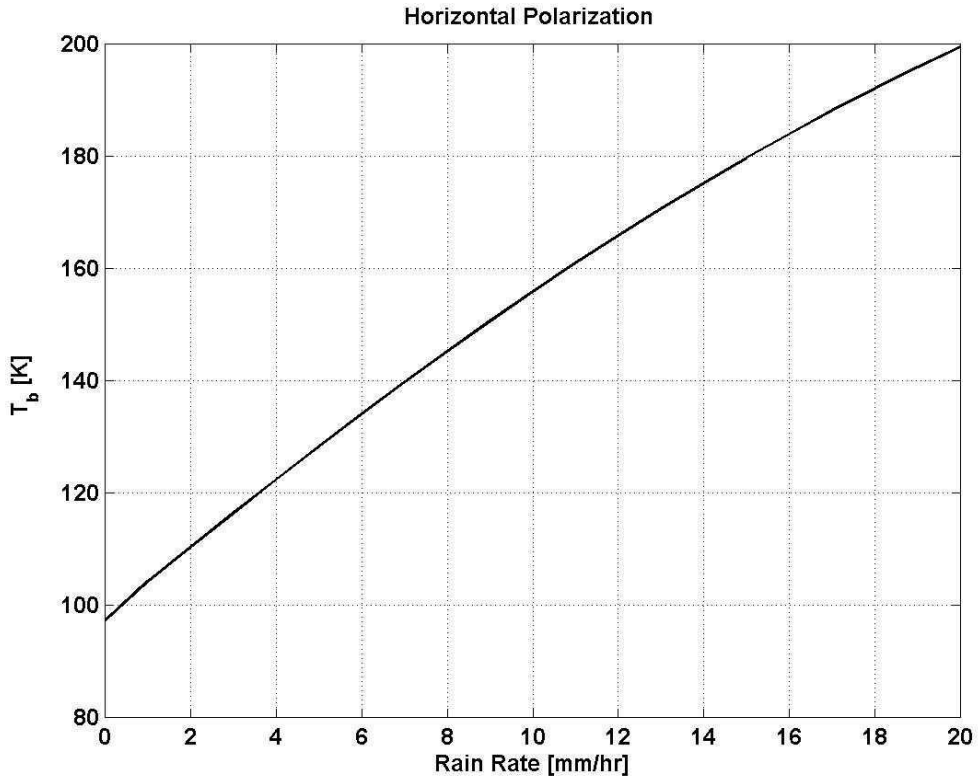


$$N_x = E_n - \beta E_e = kT_{sys}(B_n - B_e)G_n\tau$$

Effect of Precipitation on Ocean T_b

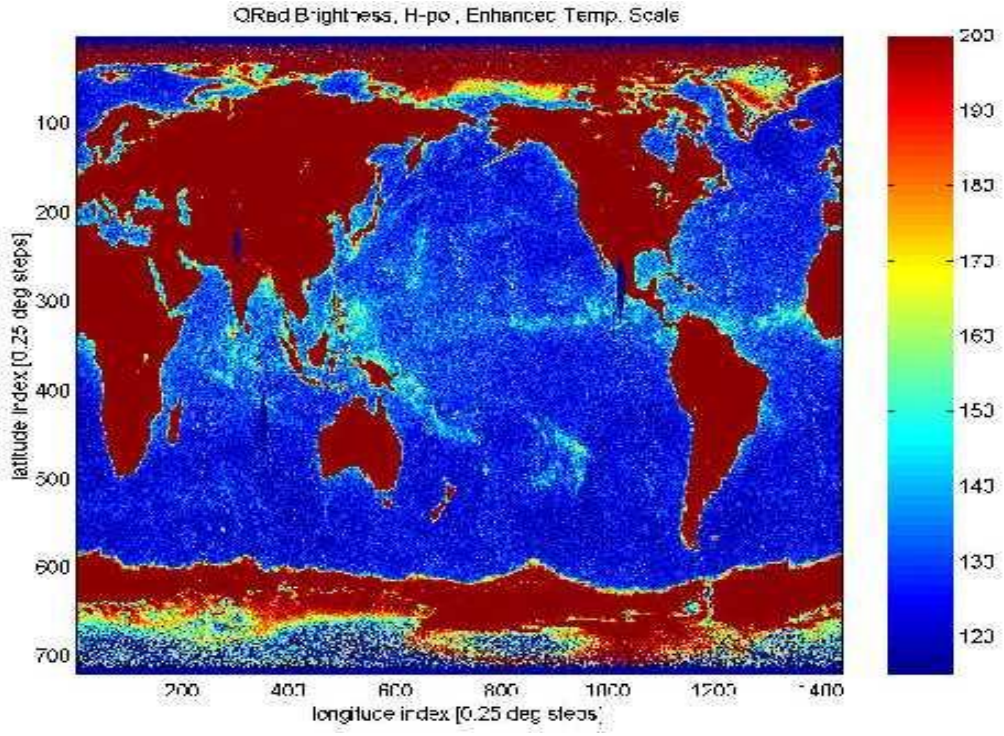
Theoretical QRad Brightness Temp. vs. Rain Rate

- General case $T_b = f(SST, ws, wv, salanity, Rain)$
- Theoretical QRad Tb $T_b = f(Rain)_{SST,ws,wv,salinity}$

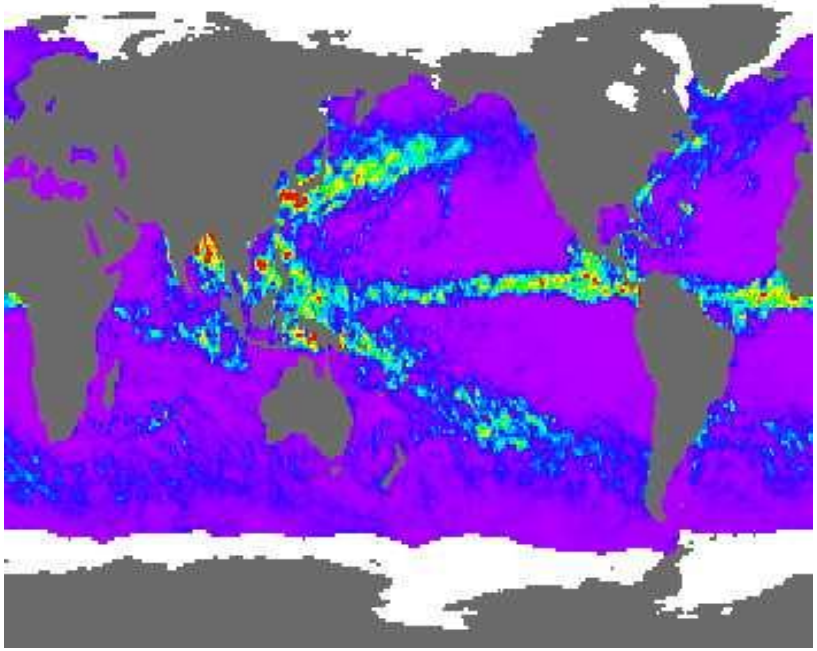


Typical Rain Signature in QRad Tb

QRad 3-Day Avg. H-pol Brightness



SSM/I Monthly Avg. Rain Rate



Rain Algorithm Definition

Advantage:

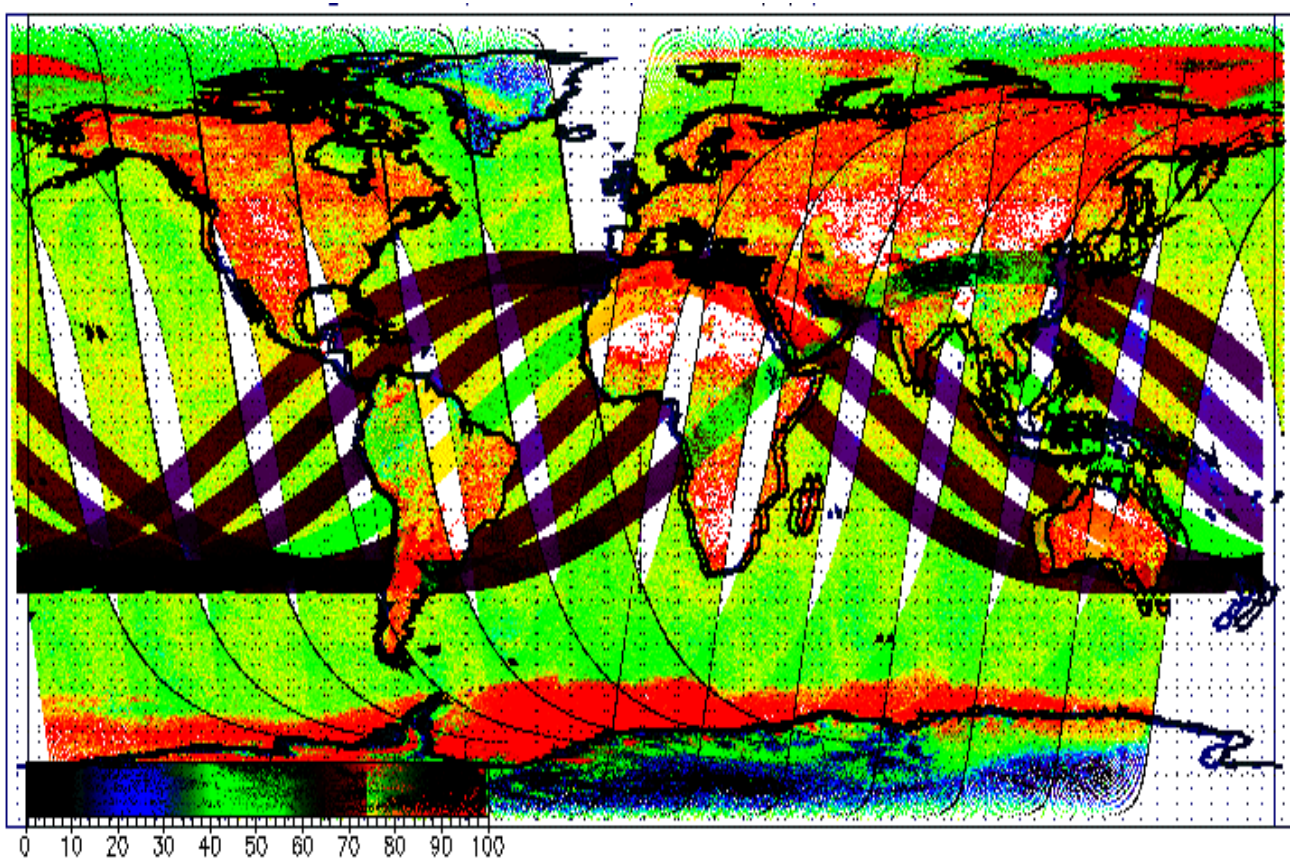
• utilization of multiple frequencies and multiple polarization enable superior accuracy of measurements.

Restrictions:

• variable spatial and time collocation with QuikSCAT wind vector cells,

• measurements just in Tropics (TMI).

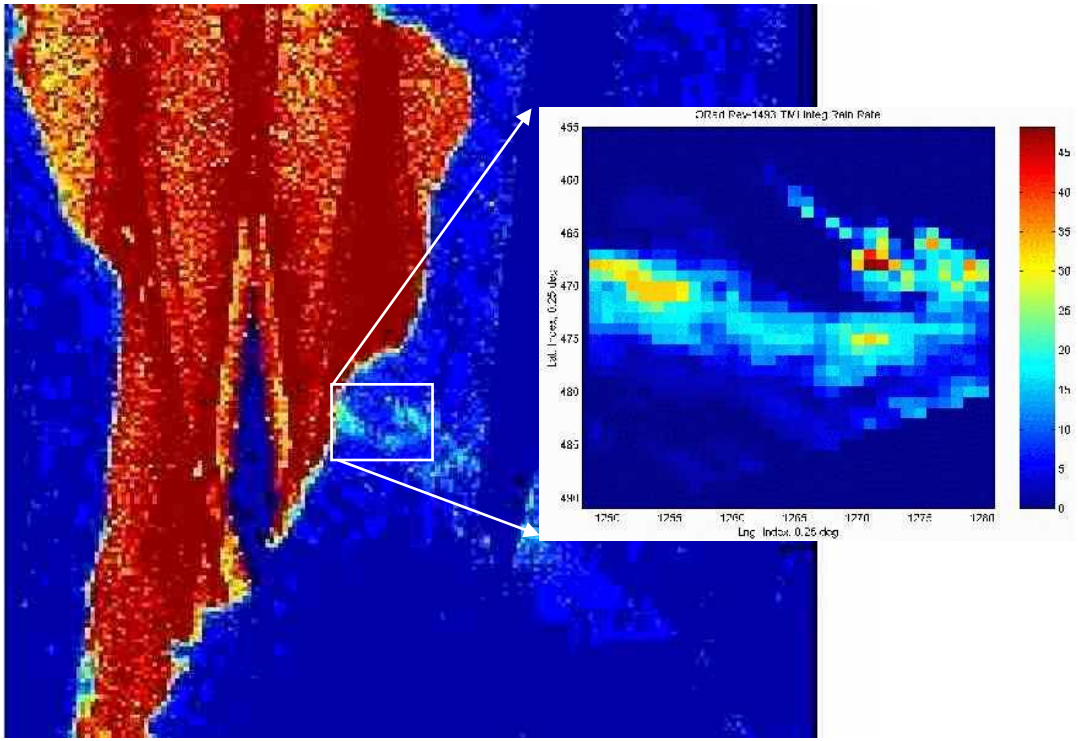
QuikSCAT and TRMM Swath



21 rain events covered by both instruments within one hour time difference used to develop the algorithm

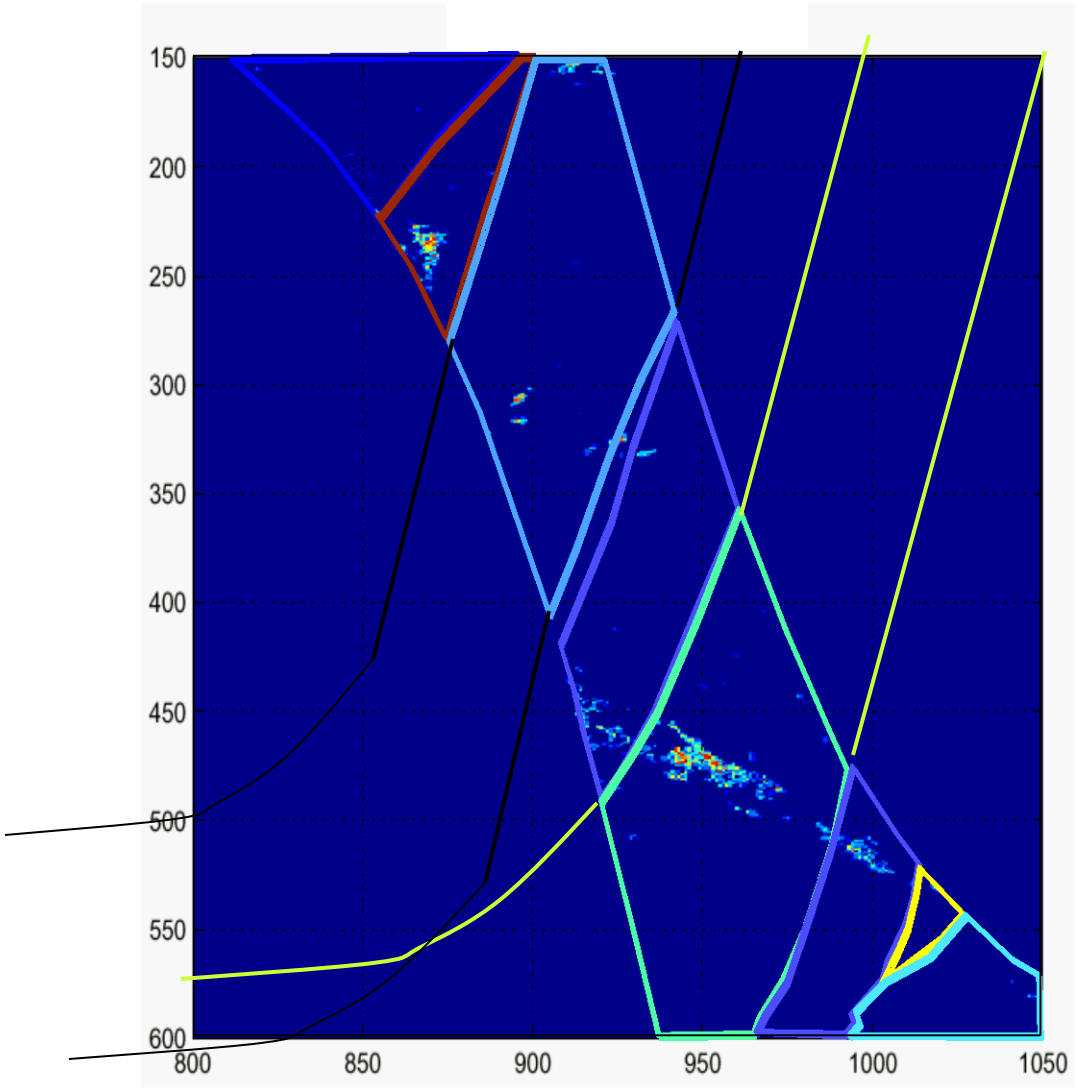
Rain Event #1493

QRad T_b



TMI
Rain Rate

Collocation of QuikSCAT and SSMI Measurements



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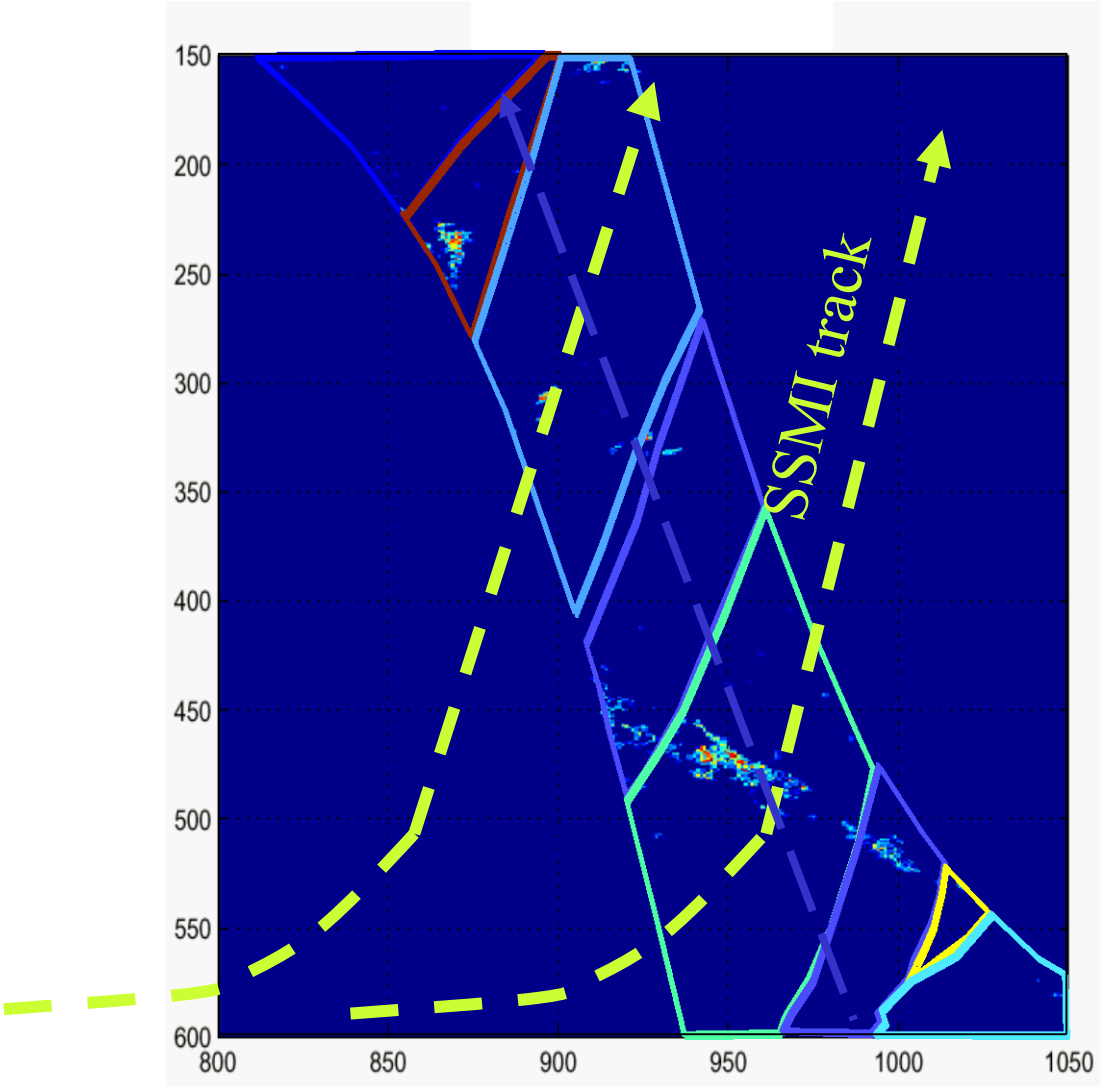
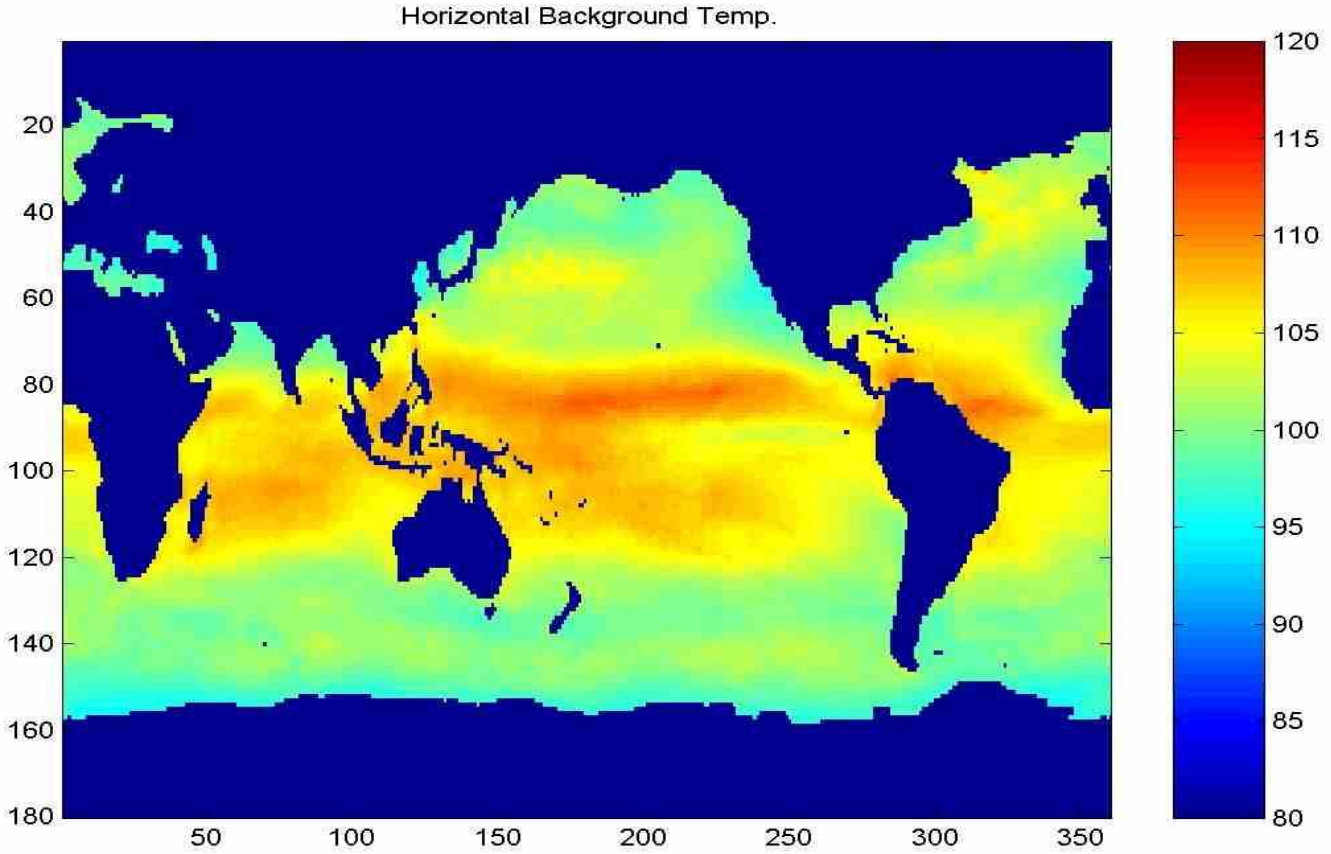
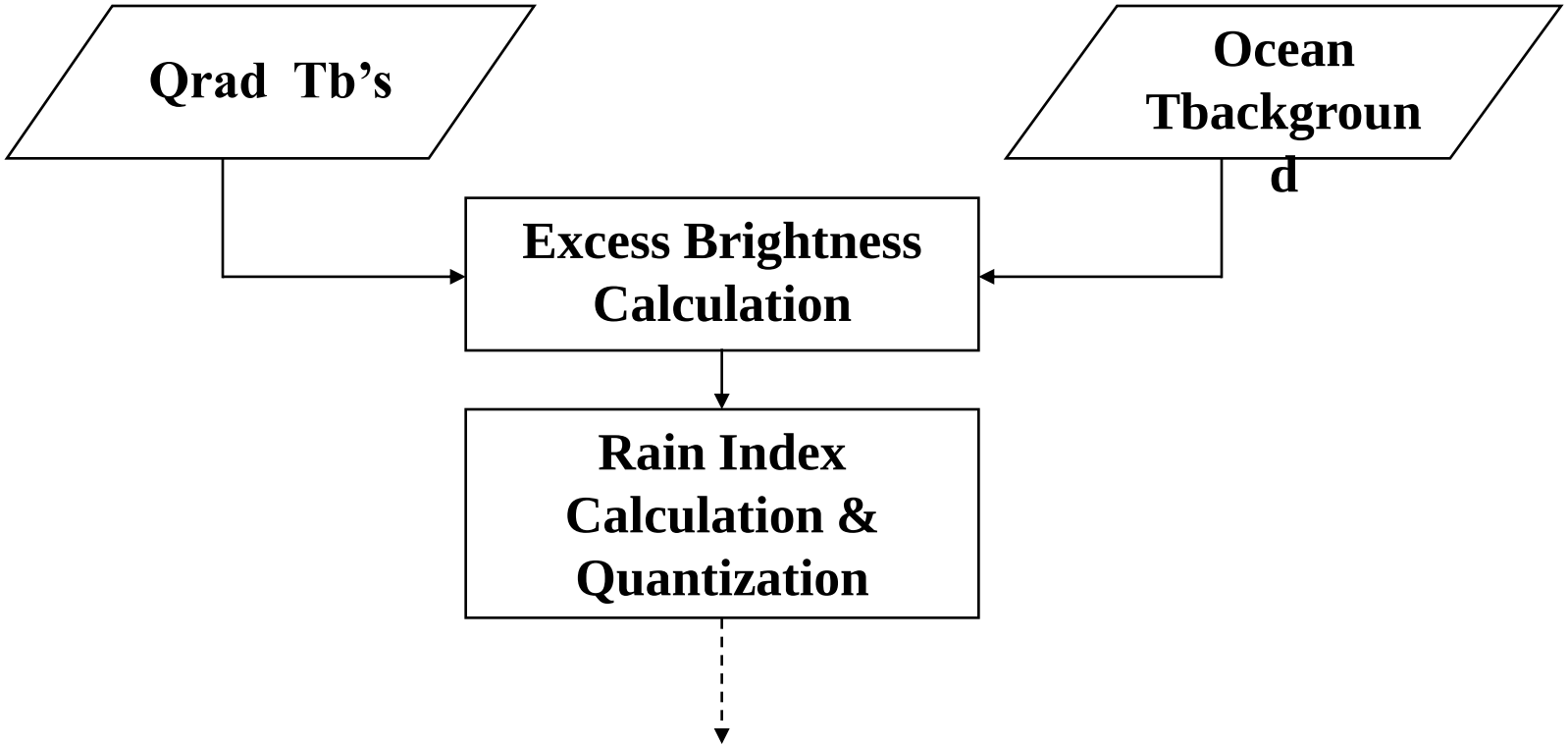


Ocean Background Brightness and "Excess Brightness"



$$\Delta T_{bp} = T_b(QRad)_p - T_b(ocean)_p$$

Flow Chart - 1st Part



Rain Index

- At QSCAT wind vector cells, calculate rain indices for both H & V-pol

$$RI_{i,j,p} = \left[\frac{<\Delta T_{b_{i,j,p}}> - \Delta T0_p}{\sigma_p / \sqrt{n_{i,j}}} \right]$$

$n_{i,j}$ … # of measurements

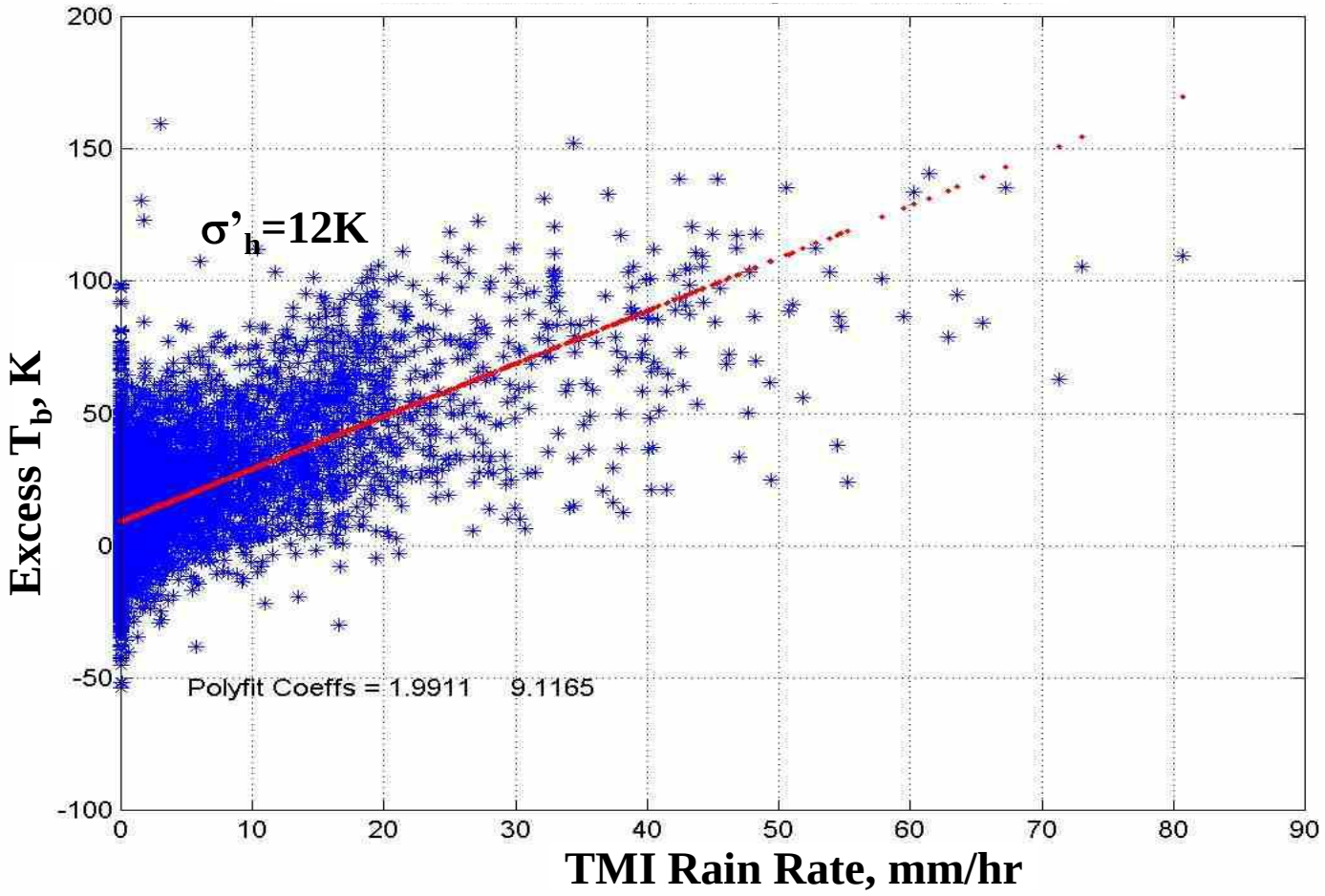
σ_p … standard deviation of T_b

i , j … bin indices

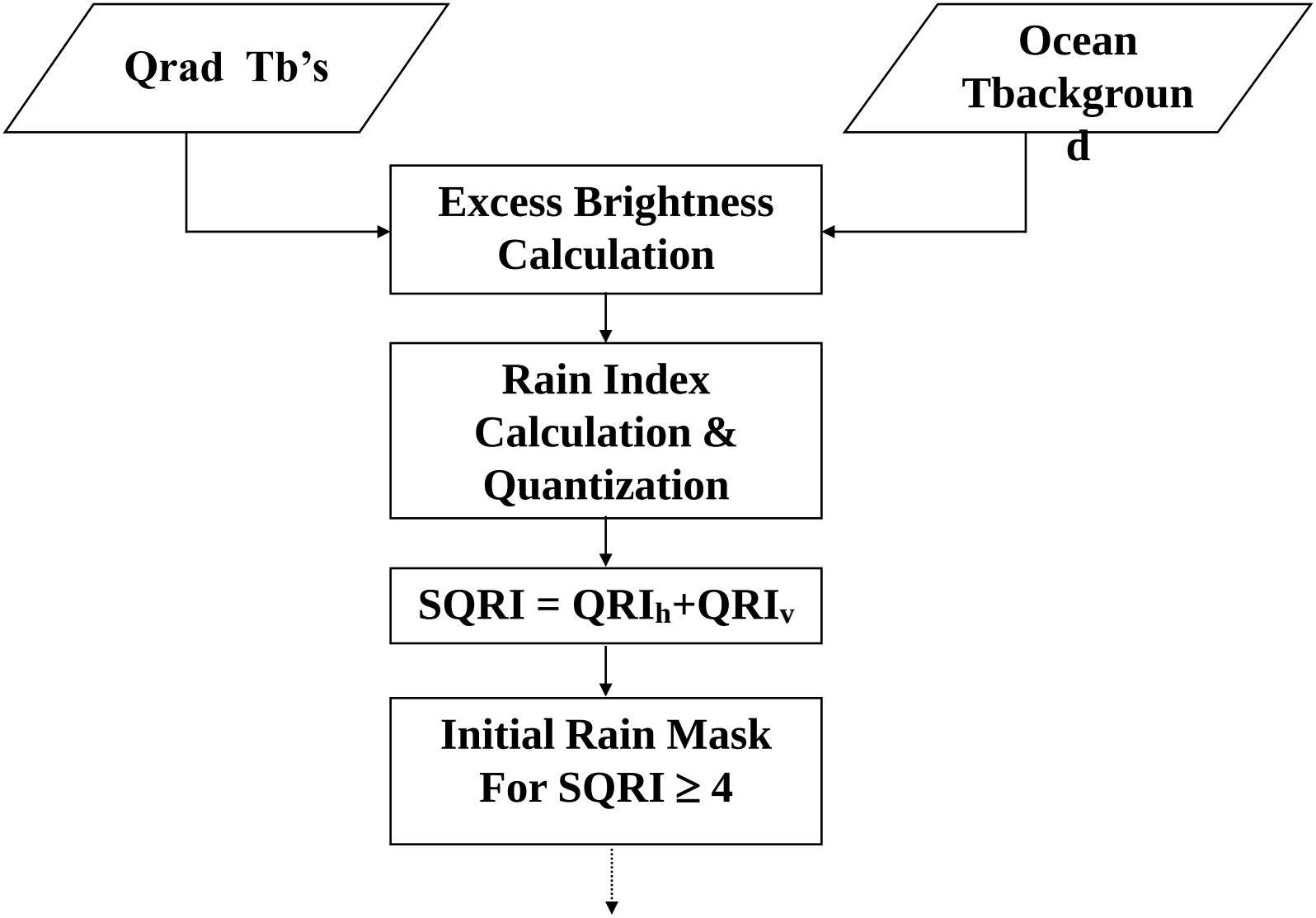
p … polarization

Brightness Temp. Offset ΔT0

Excess Brightness vs. TMI Rain Rate



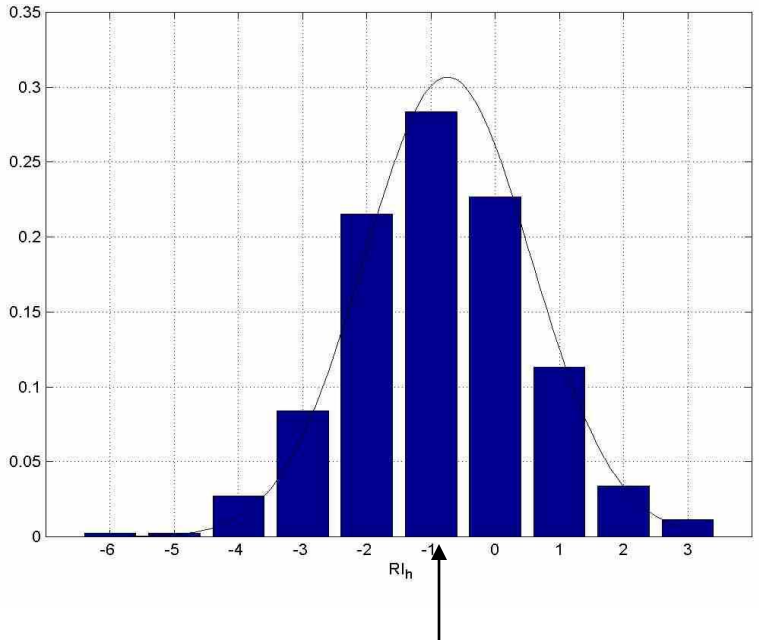
Flow Chart - 1st Part



Threshold Determination - I

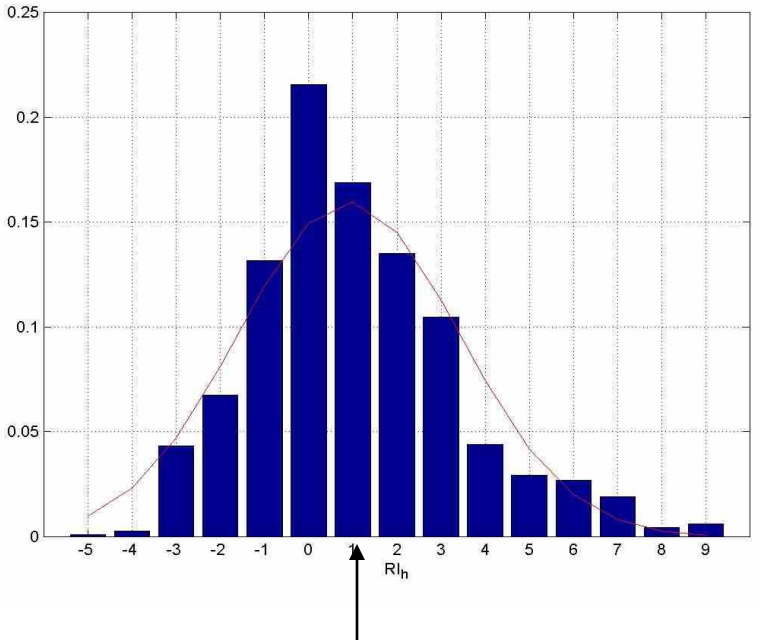
Rain Index Probability Density Functions

Clear Sky and Ocean



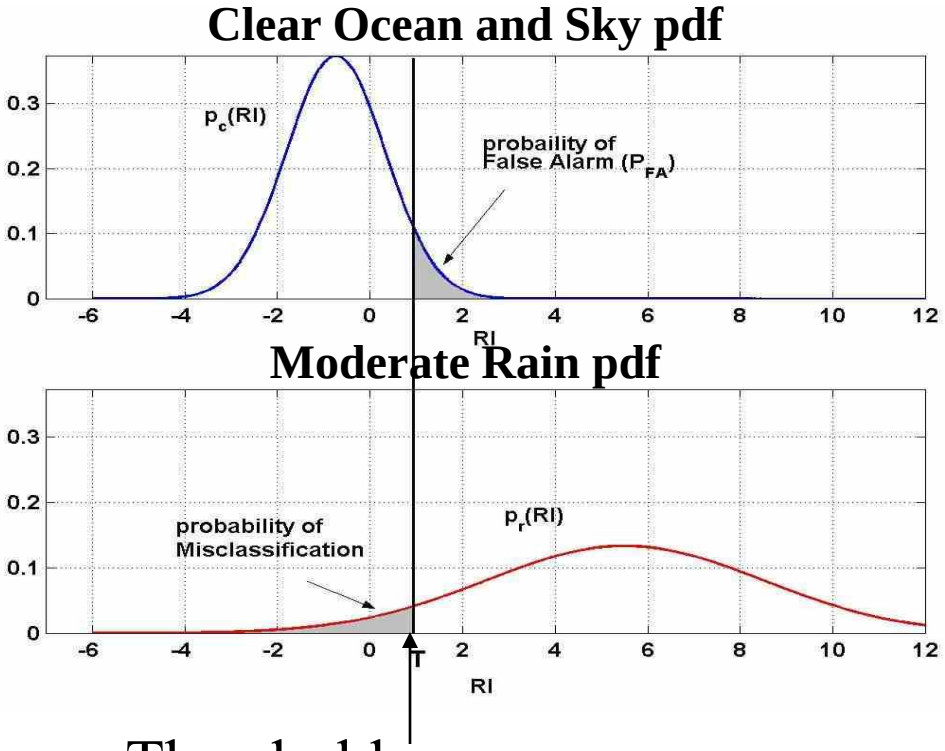
Mean QRI = - 1

Moderate Rain



Mean QRI = + 1

Threshold Determination - II



$$P_{FA} = \int_{T}^{\infty} p_c(RI)\,dRI$$

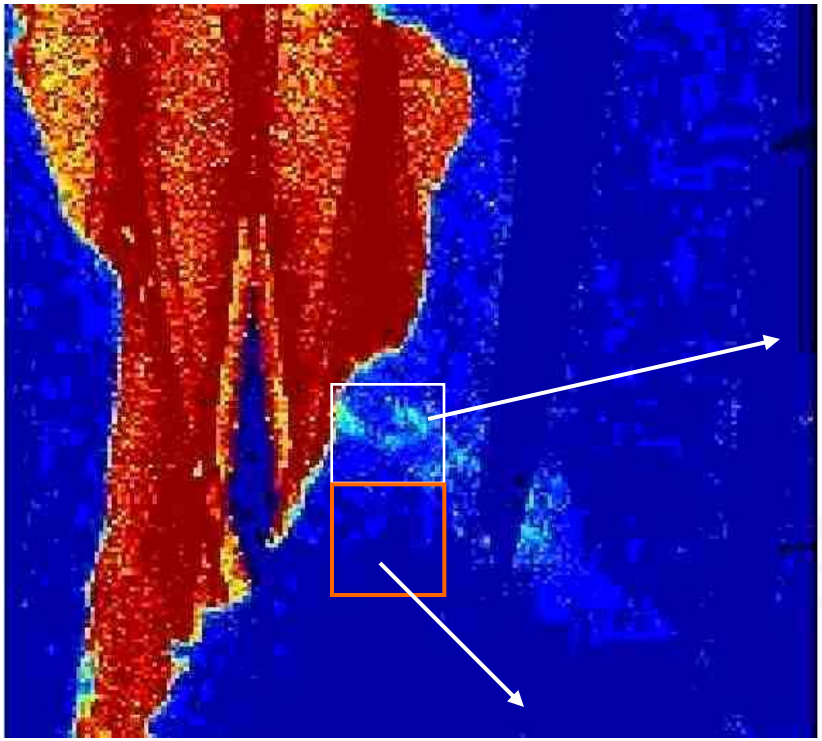
$$P_{Mc} = \int_{-\infty}^{T} p_r(RI)\,dRI$$

$$P_E = P_{Mc} + P_{FA}$$

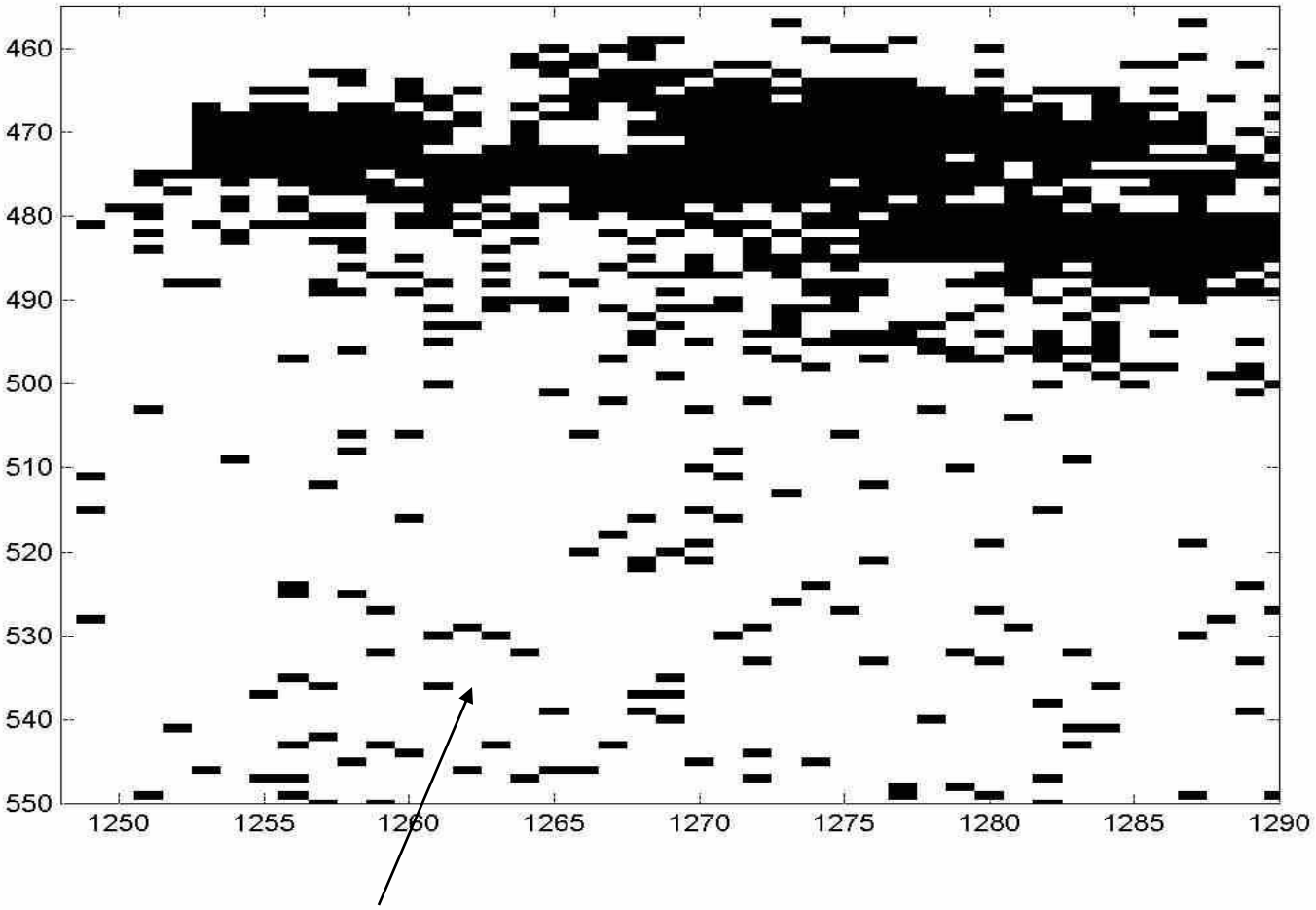
Threshold "T" is defined where P_E has minimum !!

Rain Event #1493

QRad T_b

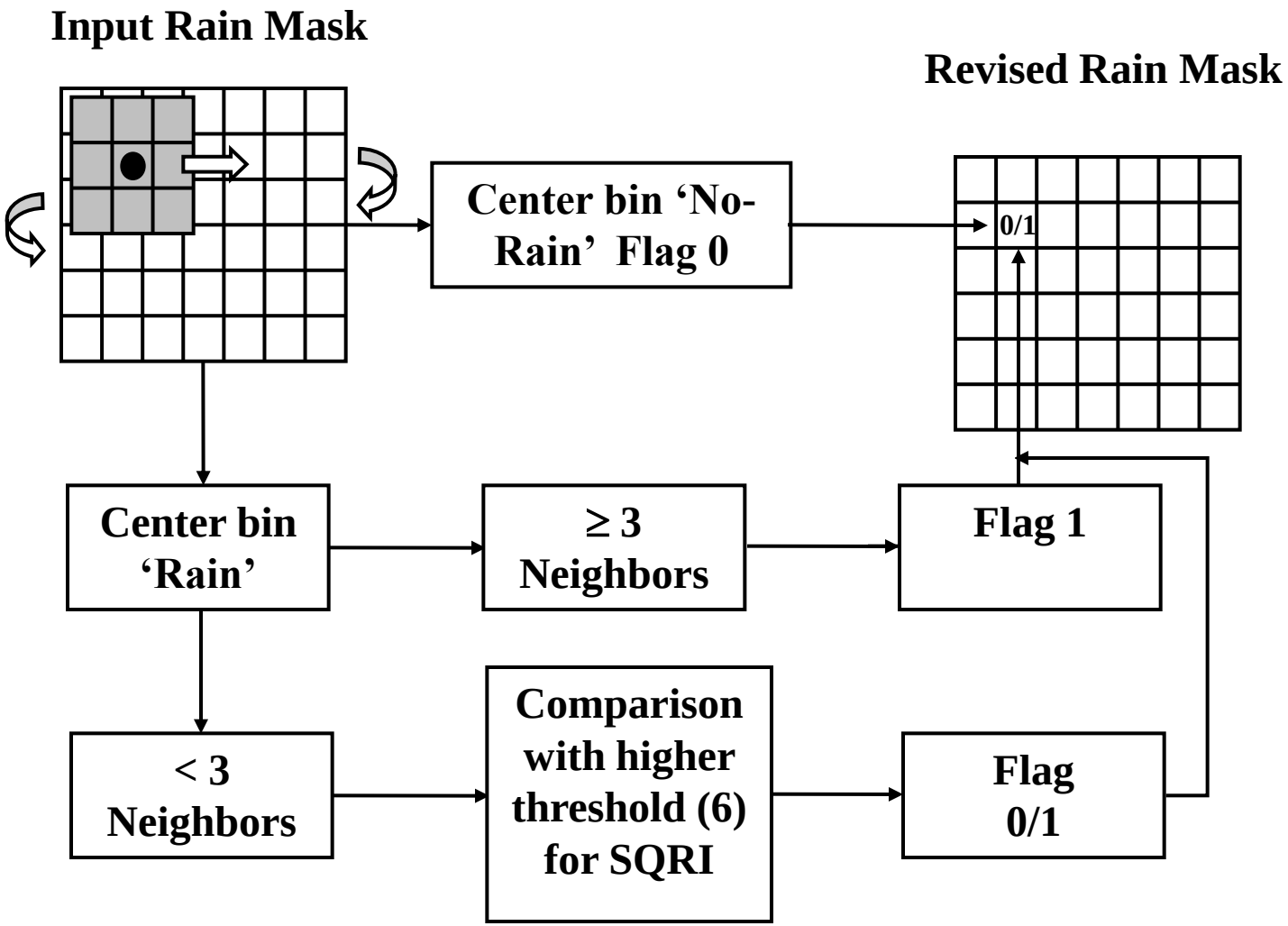


Initial Rain Mask - Input to Spatial Filter



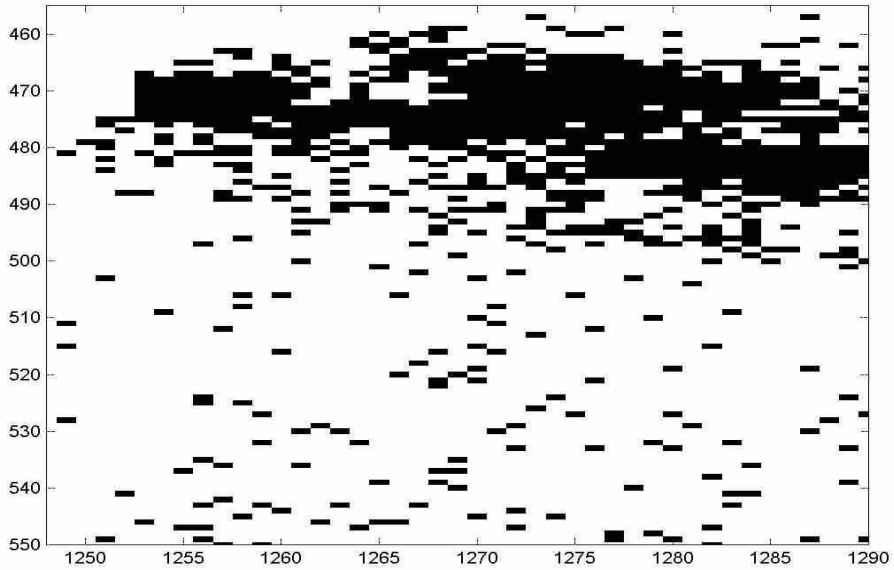
Random Rain False Alarms

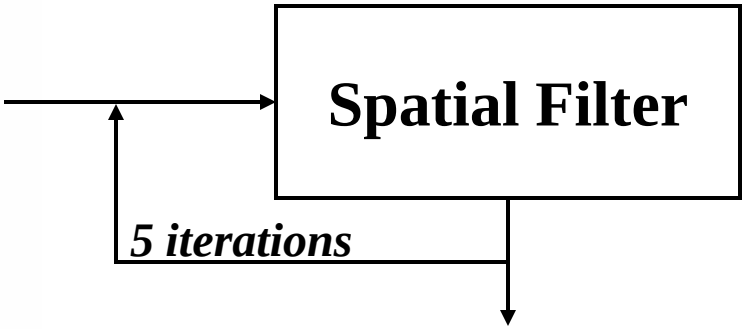
Flow Chart - 2nd part Spatial Filter



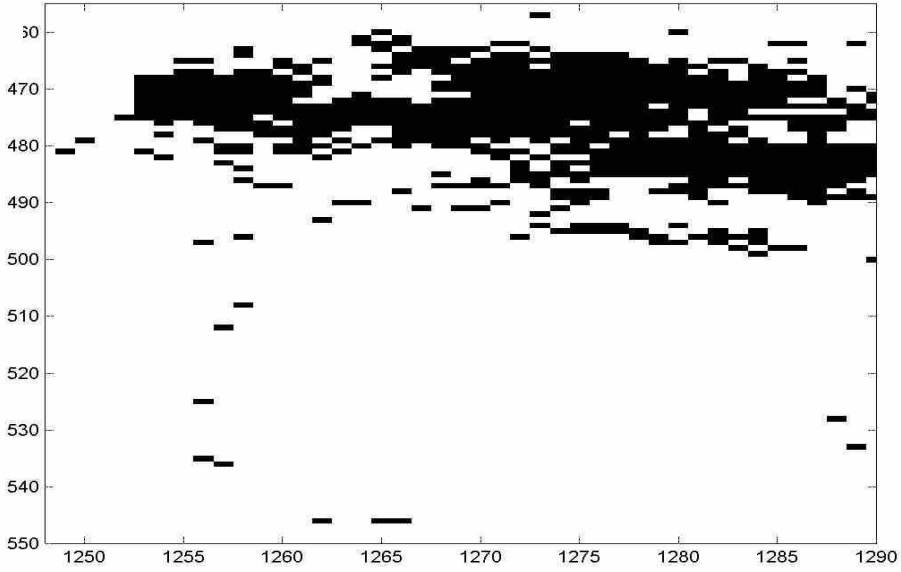
Spatial Filter Performance

Input

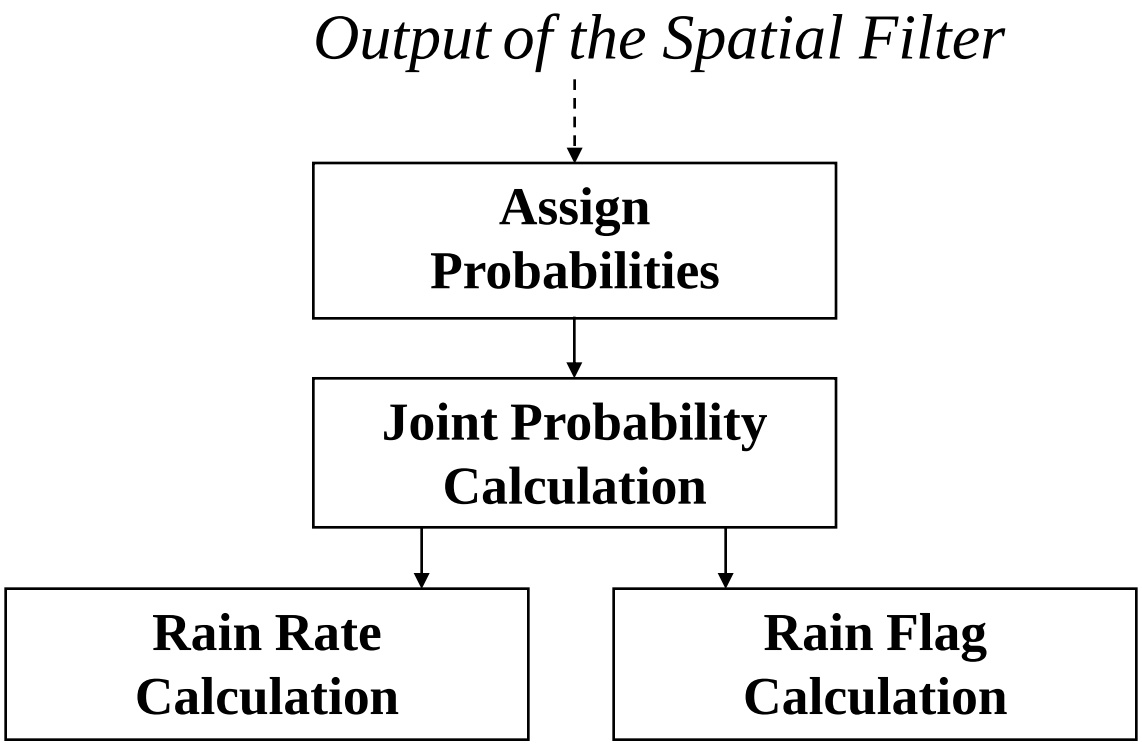




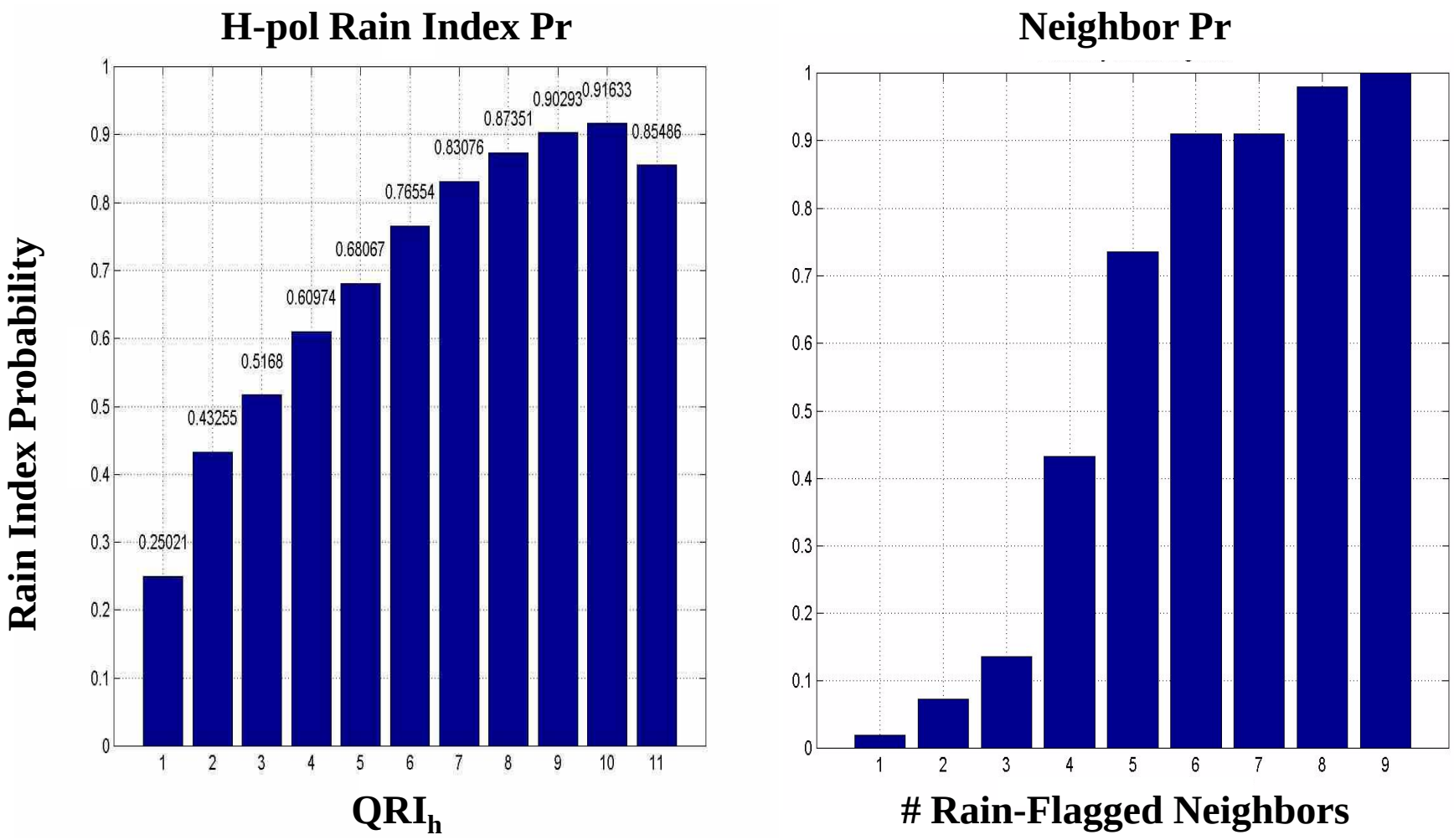
Output



Flow Chart - Part-3



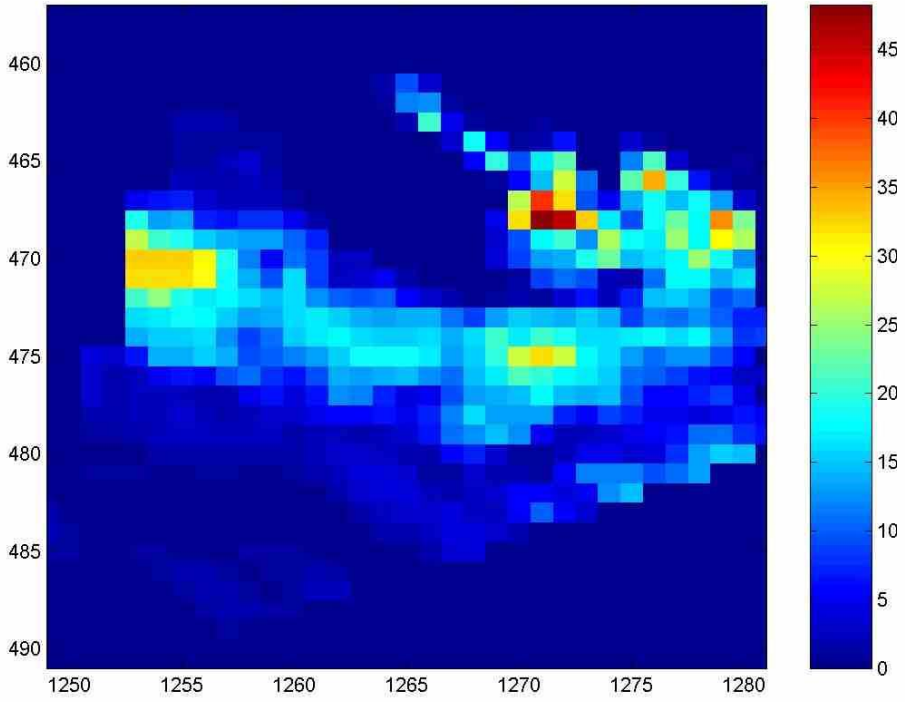
Rain Index Probability and Neighbor Probability



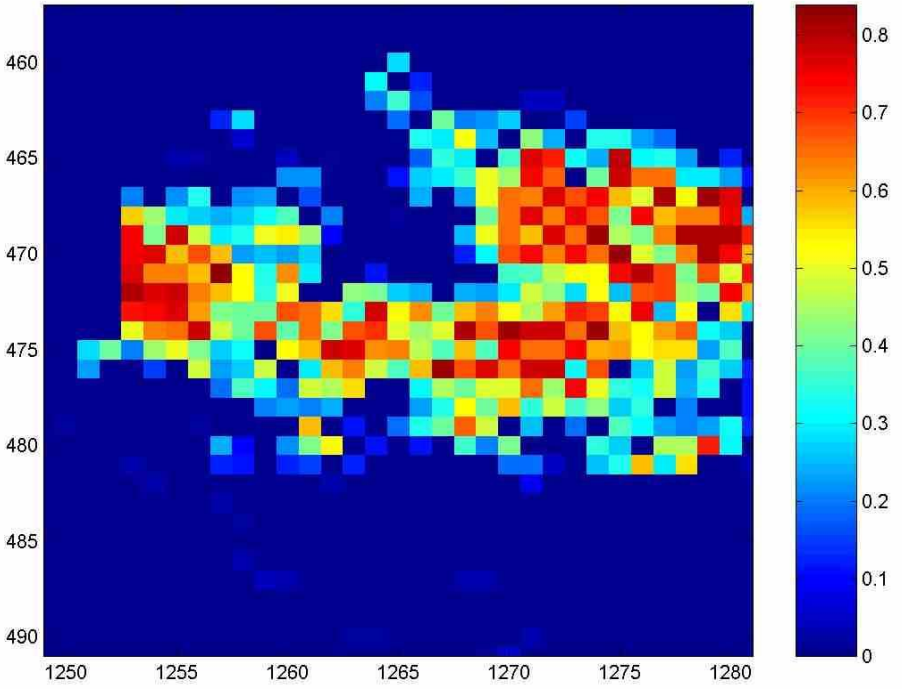
QRad Joint Probability

$$JP = \Pr(Nbs) \cdot \Pr_h(QRI) \cdot \Pr_v(QRI)$$

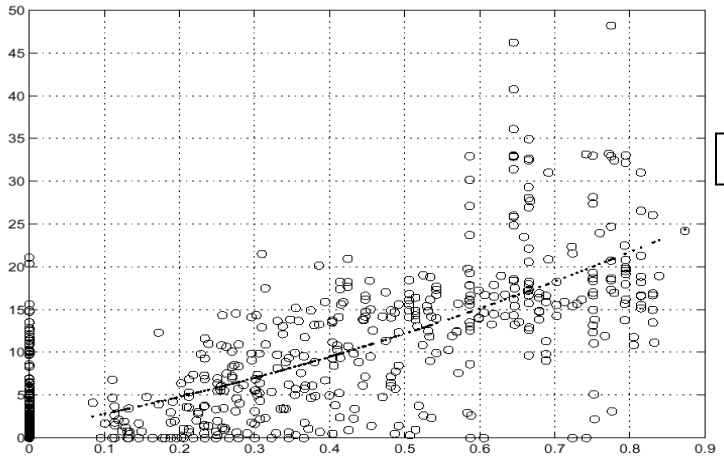
TMI Rain Rate



QRad Joint Pr

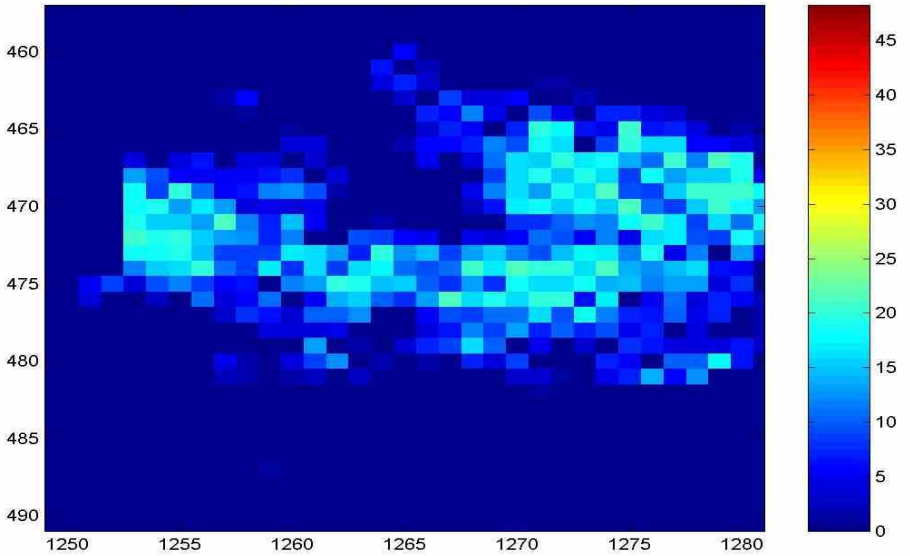


QRad Rain Rate

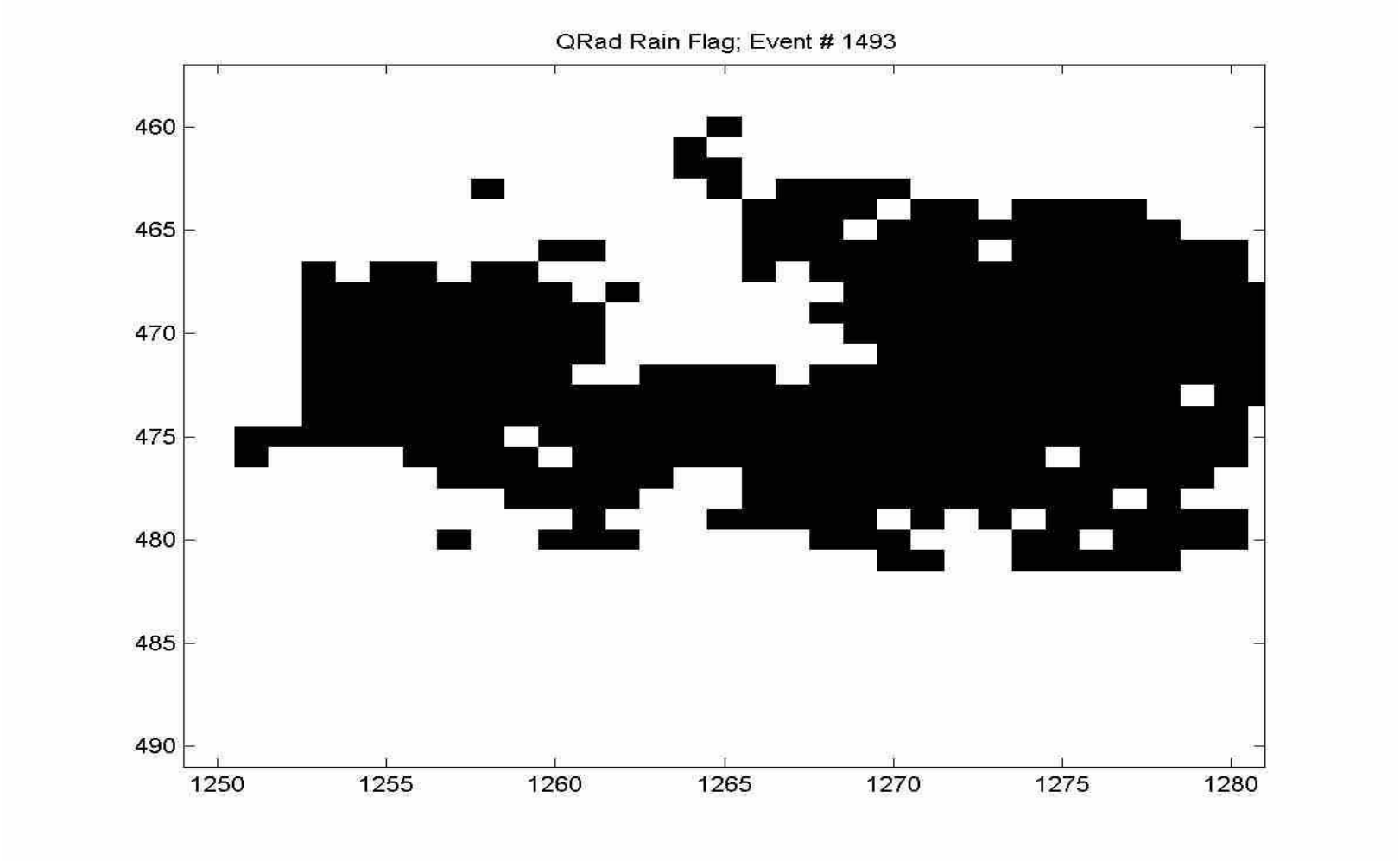


Regression TMI Rain Rates with Joint Probabilities gives the expression;

$$RR = A \cdot JP^2 + B \cdot JP$$



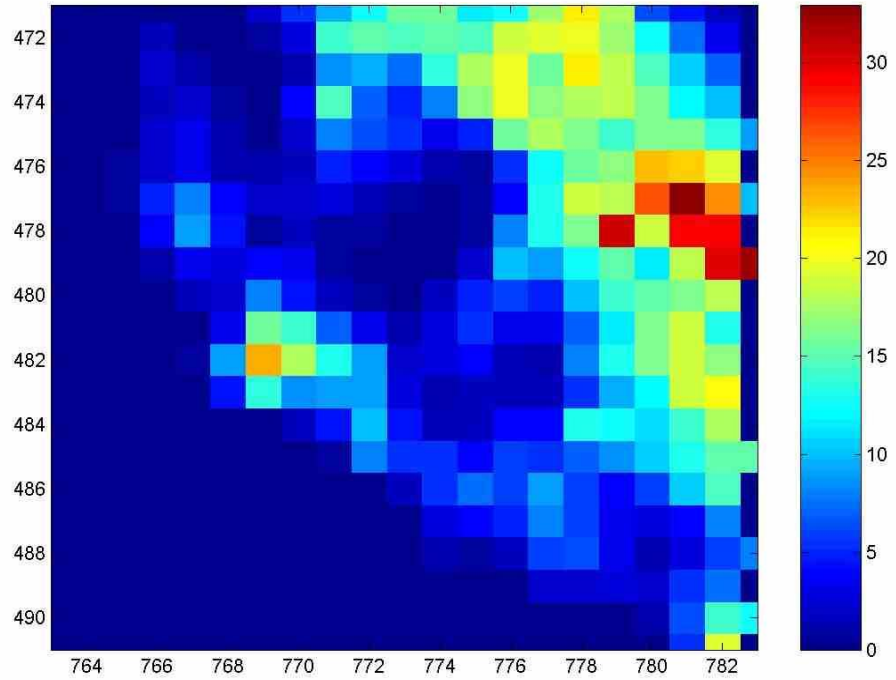
QRad Rain Flag



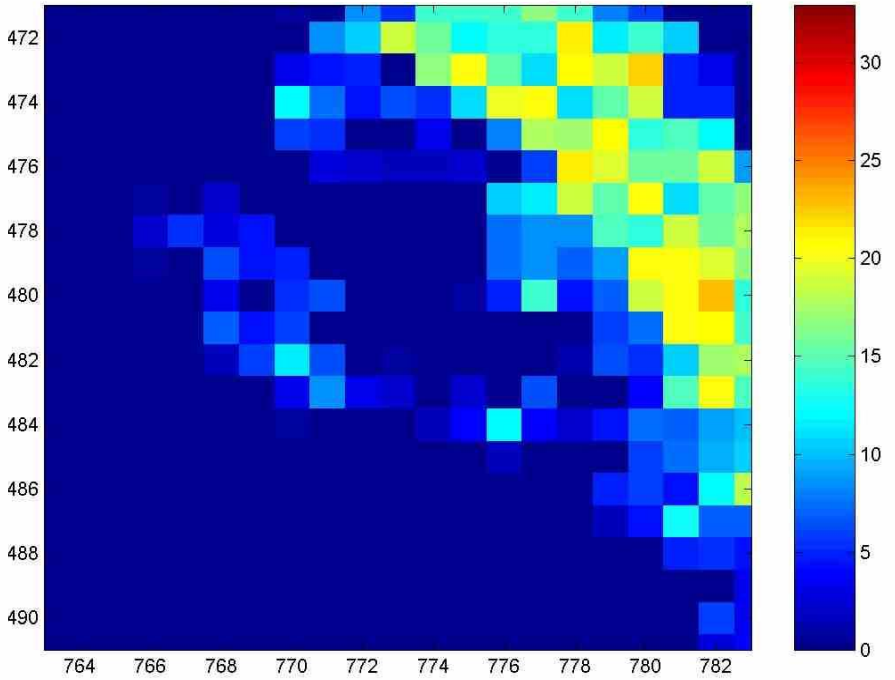
Rain Algorithm Validation and Results

Rain Rate Comparison with TMI - Rain Event #1176

TMI



QRad

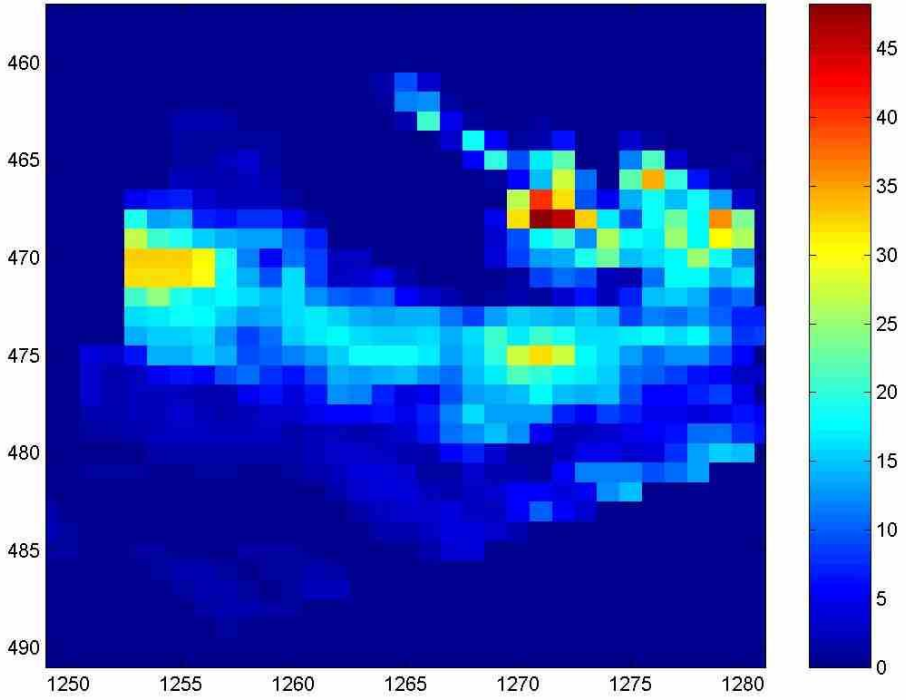


Accumulative Rain Rate, mm

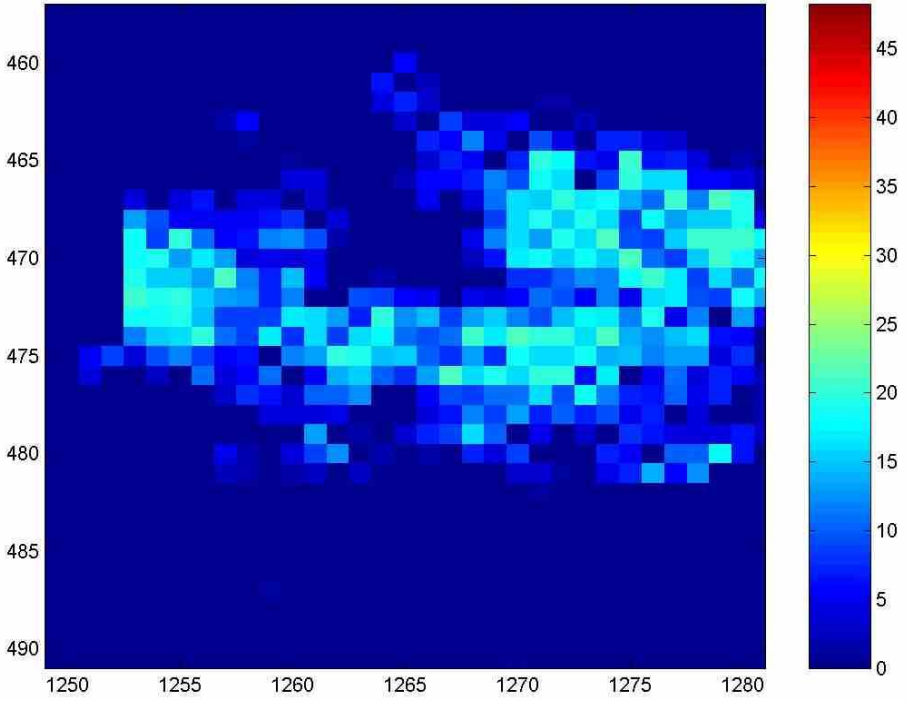
TMI	QRad	QRad/TMI
2,462	1,750	0.71

Rain Rate Comparison with TMI - Rain Event #1493

TMI



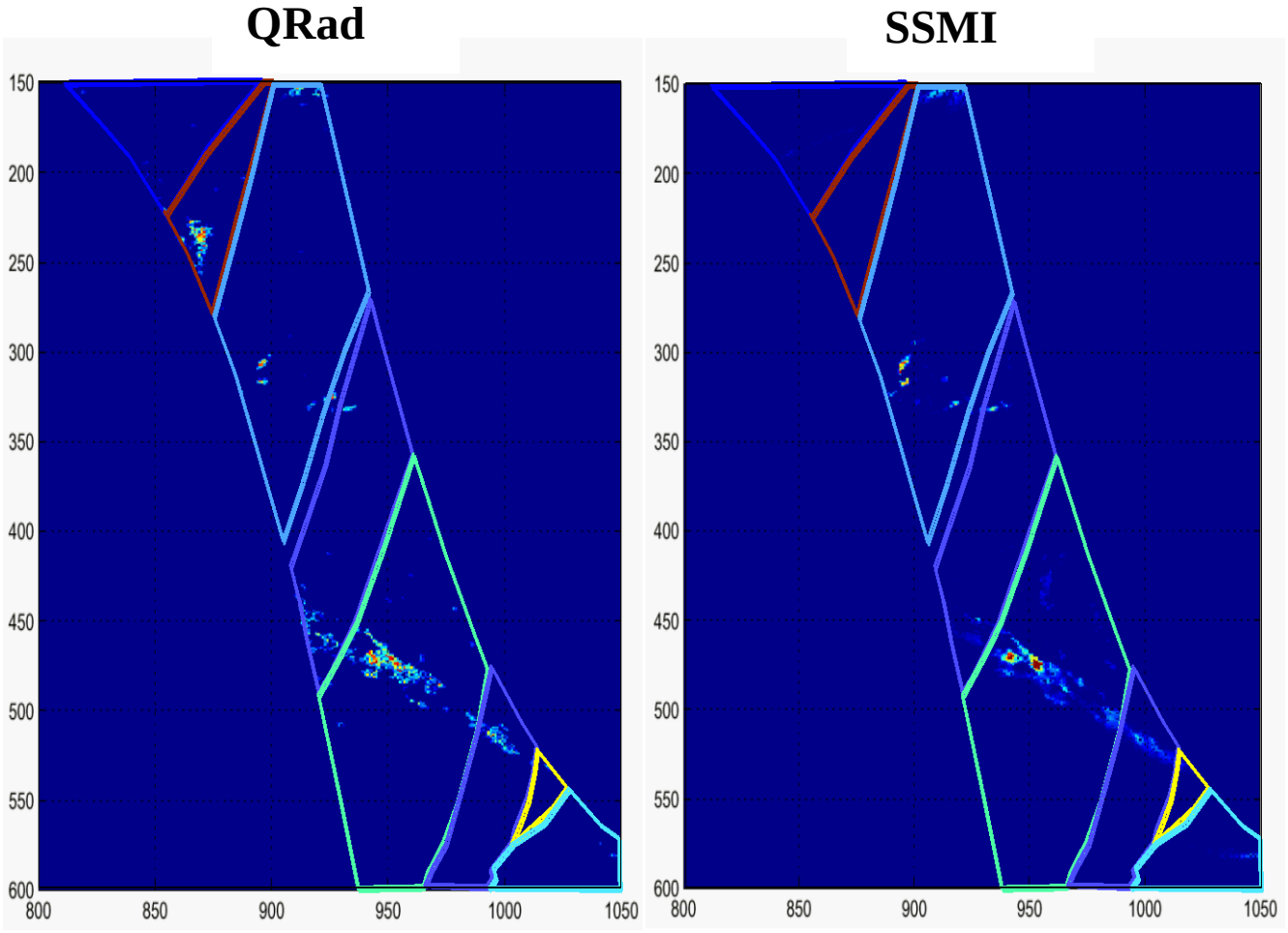
QRad



Accumulative Rain Rate, mm

TMI	QRad	QRad/TMI
5,745	4,701	0.82

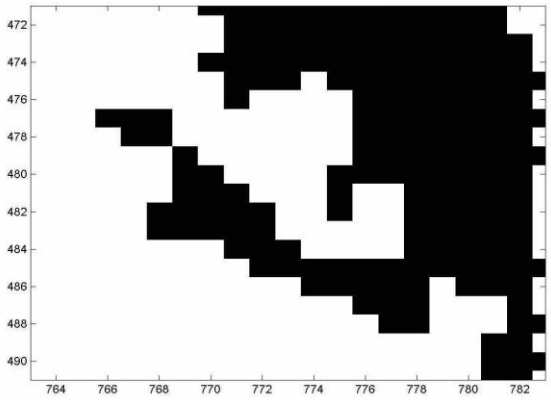
Rain Rate Comparison with SSMI - QuikSCAT Rev #1439



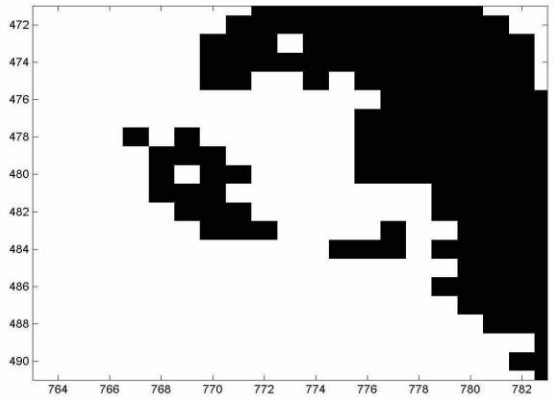
Accumulative Rain Rate, mm	QRad	SSMI	QRad/SSMI
	4473	4539	0.99

Rain Flag Classification - Rain Event #1176

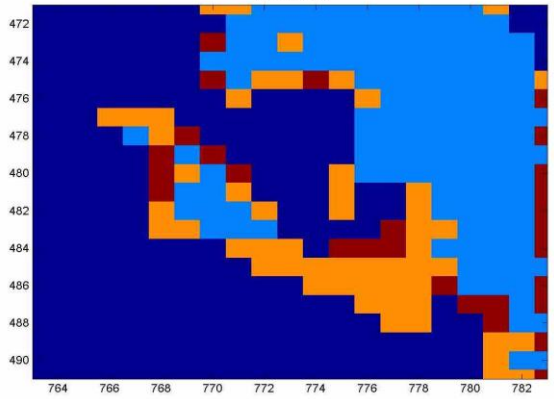
TMI



QRad



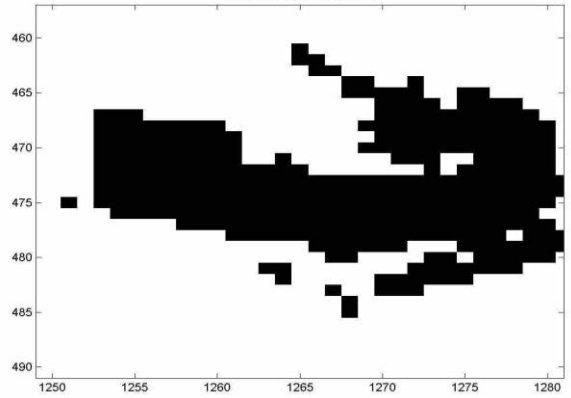
Classification



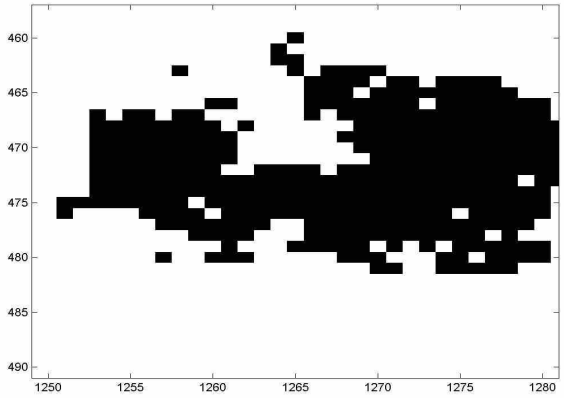
Correct No-Rain	**(89.27%)**
Correct Rain	**(70.00%)**
Misclassification	**(30.00%)**
False Alarm	**(10.73%)**

Rain Flag Classification - Rain Event #1493

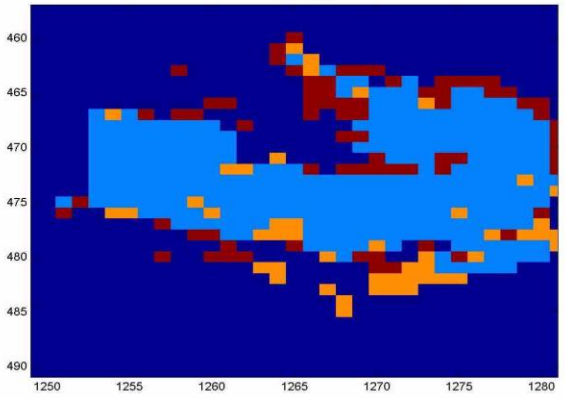
TMI



QRad



Classification



Correct No-Rain	**(88.86%)**
Correct Rain	**(85.67%)**
Misclassification	**(14.33%)**
False Alarms	**(11.14%)**

Conclusion

- A statistical rain rate retrieval algorithm has been developed using QRad T_b's and rain rates derived from TRMM TMI.

- Also a binary rain flag has been produced using 1.4 mm/hr as the threshold.

- Comparisons between QRad, TMI & SSMI rain rates show excellent spatial correlation when properly collocated in time.

- Some solutions and procedures proposed in this thesis have been accepted by the sponsor of the project, JPL, and implemented into operational SeaWinds rain algorithm.