Spatial Variability of Surface Rainfall and its Impact on Radar Retrieval

by

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Objective

- Broad Perspective: Improved Estimate of Rainfall
  - What is the observed variability of rainfall?
  - Does this variability affects remote or in-situ measurement of precipitation?
  - To find a mechanism to properly match different observations for calibration or validation purpose.
- Specific Mission: Tropical rainfall Measuring Mission (TRMM)

Organization of the Thesis

Chapter 1
- Relevance
- Objective
- Overview

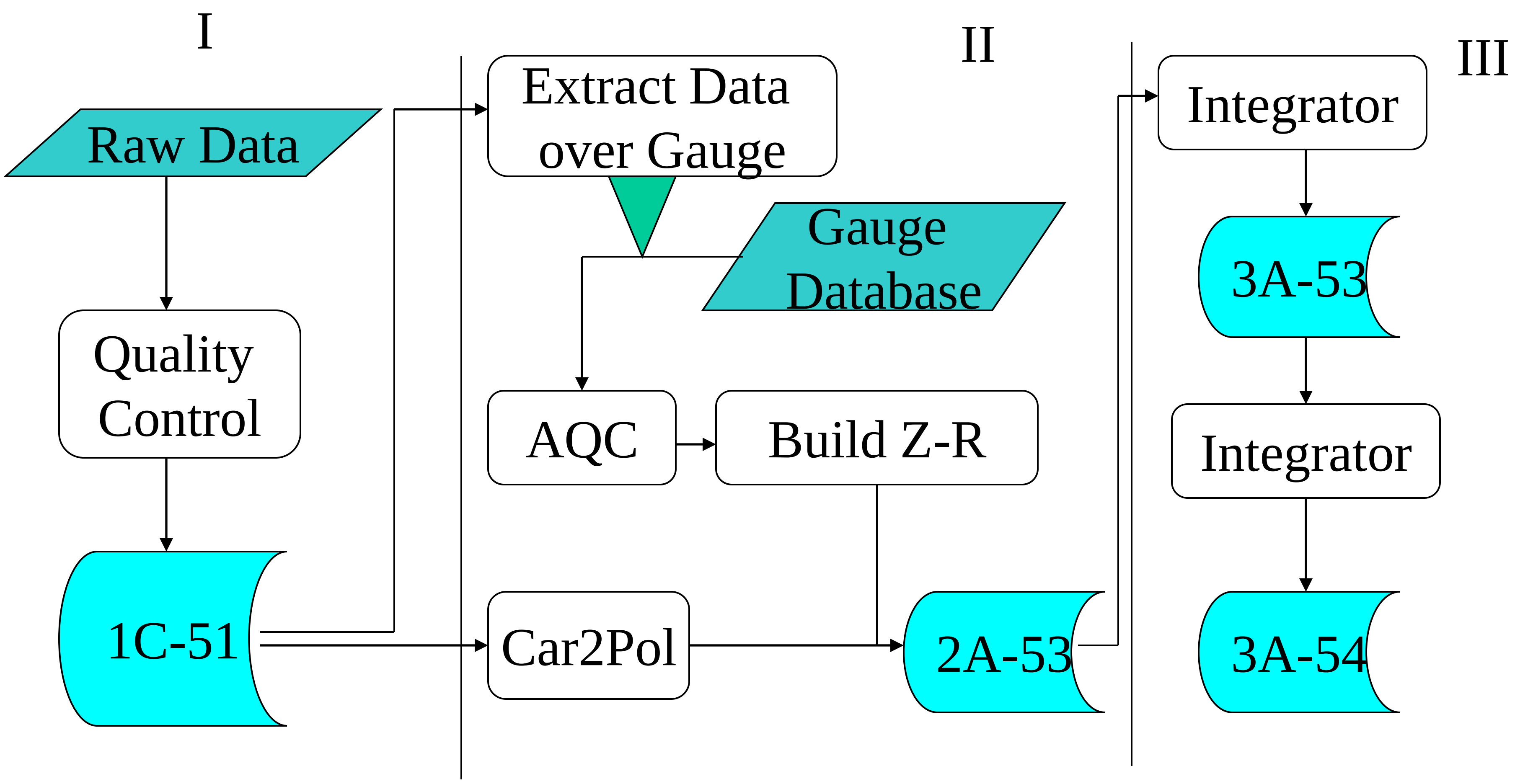
Chapter 2
- Basics
- How's and What's
- Z-R

Chapter 3
- Variability
- De-correlation
- Error Analysis

Chapter 4
- Spatial-temporal matching method
- Improvements

Chapter 5 — Summary & Conclusions

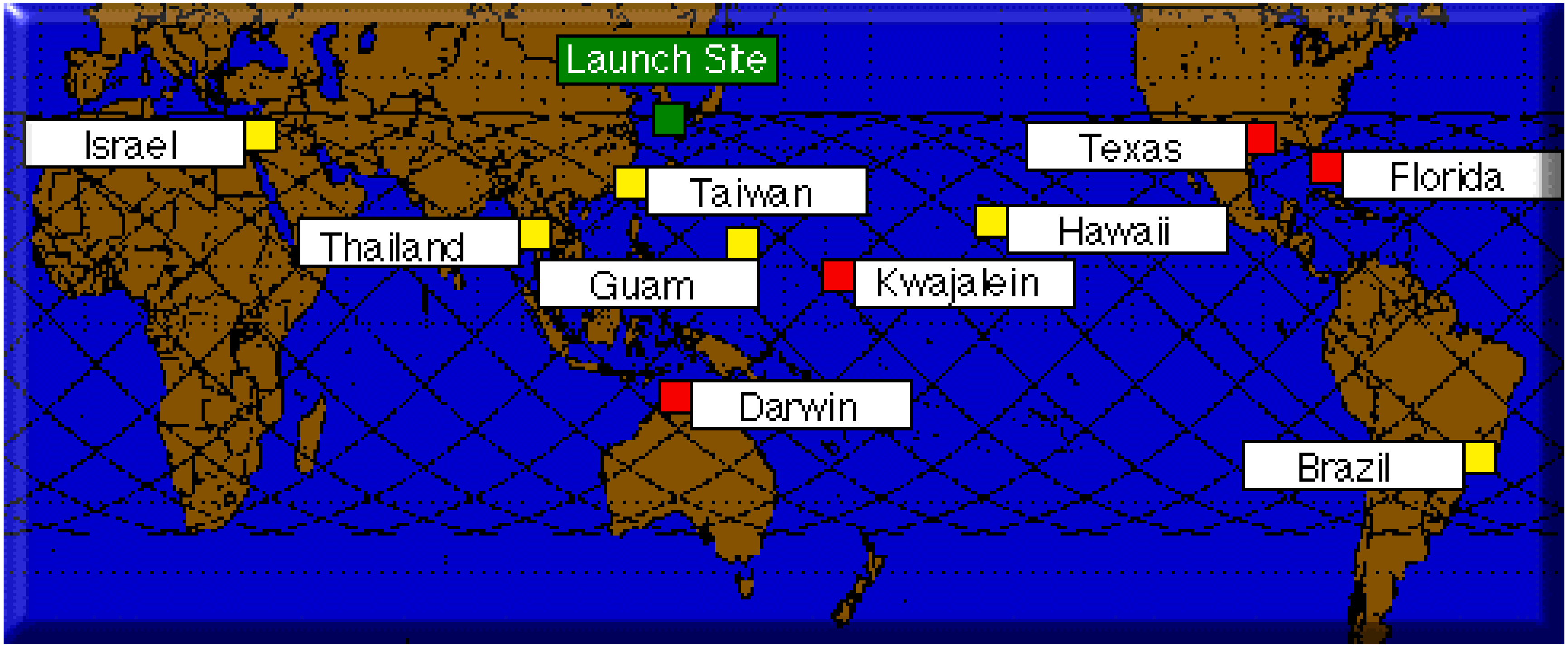
Rainfall From Radar



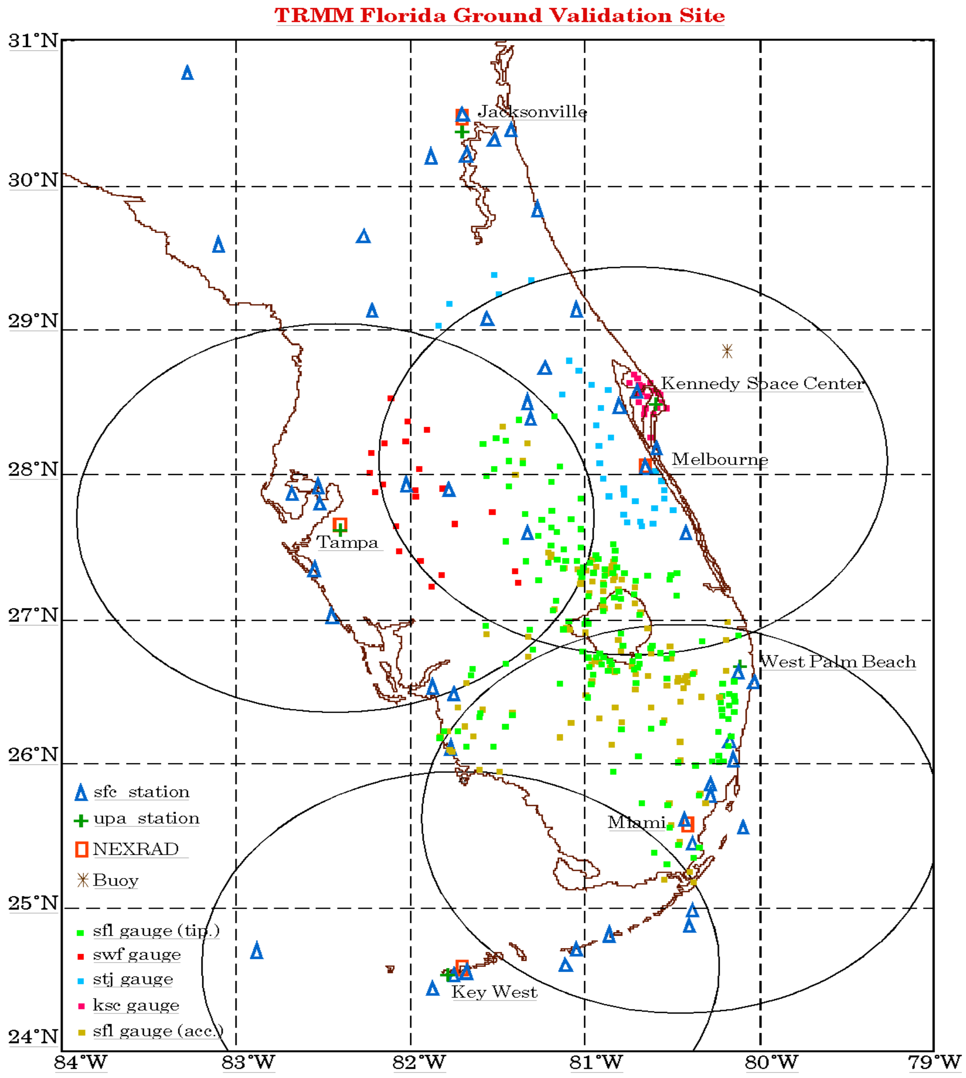
Identified Problems

- The major problem in radar data processing is in level II
- *Volume averaged* radar reflectivity calibrated against *point* gauge measurement.
- Issues:
  - Difference in spatial and temporal resolution of two sensors
  - Quality of the gauge data used.
  - Appropriateness of the way Z-R is derived and applied.

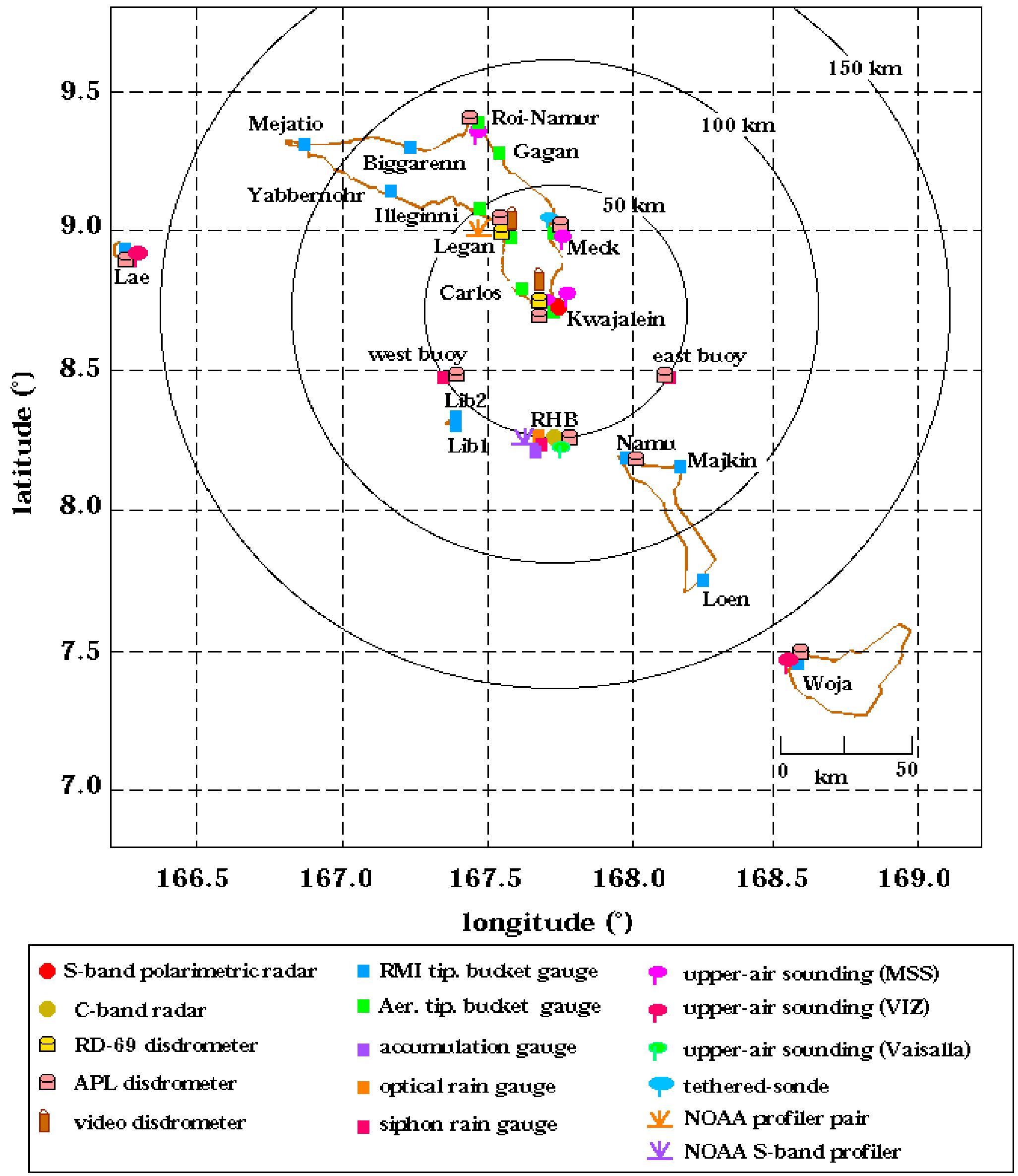
TRMM Global Validation



Courtesy:TRMM Office Web Page


TRMM Florida Ground Validation Site
31°N
30°N
29°N
28°N
27°N
26°N
25°N
24°N
84°W
83°W
82°W
81°W
80°W
79°W
Jacksonville
Kennedy Space Center
Melbourne
Tampa
West Palm Beach
Miami
Key West
sfc station
upa station
NEXRAD
Buoy
sfl gauge (tip.)
swf gauge
stj gauge
ksc gauge
sfl gauge (acc.)

KWAJEX Observational Network



Data Used

- The analysis is carried out for two sites: (KMLB) Melbourne FL and (KWAJ) Kwajalein at RMI.
- For KMLB, the TRMM Ground Validation monthly and pentad products for August and September 1998 are used. For KWAJ University of Washington (UW) monthly rainfall products are used.
- The products are in 2 km x 2 km grid in the base scan plane.

Dual or Single Z-R?

- Dual Z-R : Two different Z-R relationships for convective and stratiform type of rain (different DSD's)

Table 2.3, Chapter 2

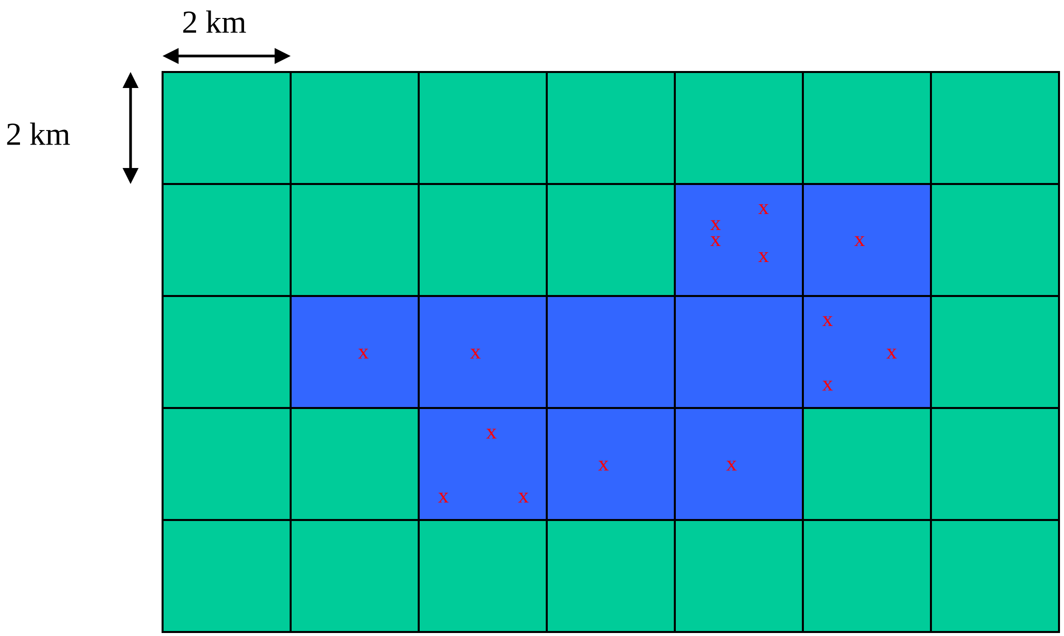
August 1998 ΣR/ΣG ratios

Net	Type	Conv.	Strat.	Total
KSC	**Dual**	0.86	1.05	0.89
	Single	0.83	1.23	0.89
SFL	**Dual**	1.15	1.10	1.14
	Single	1.11	1.30	1.14
STJ	**Dual**	0.96	0.85	0.94
	Single	0.93	0.99	0.94
ALL	**Dual**	0.99	1.00	0.99
	Single	0.96	1.17	0.99

Results on Z-R Analysis

- For 08/98 and 09/98, approximately 80% rainfall was convective in nature.
- Both dual and single Z-R yields similar total rainfall for the month.
- For individual categories, single Z-R overestimated stratiform rainfall.
- Different comparisons are obtained after single parameter adjustment over different networks.

The DRGN Network

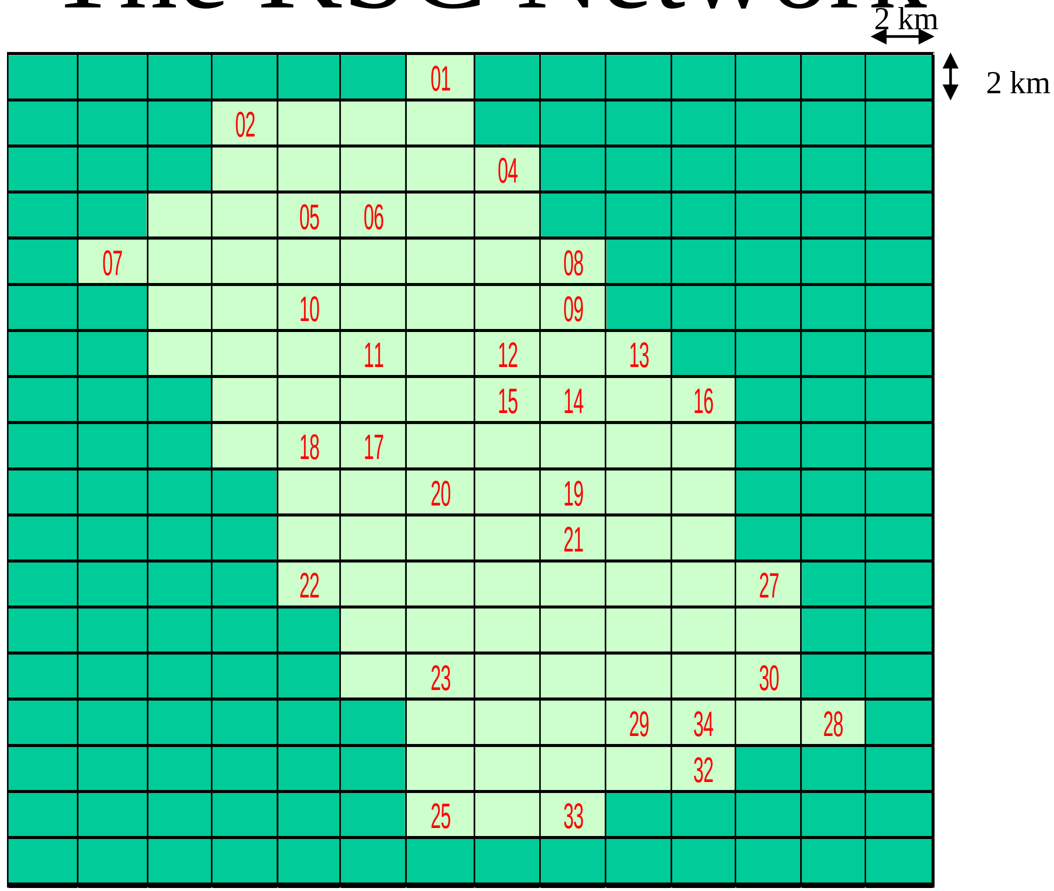


Located approximately 40 km WSW of Melbourne NEXRAD (KMLB)

The lowest elevation beam (0.48° inclination, from which the surface rainfall is derived) is approximately at 423 m height above ground over DRGN.

Total 14 x 10 sq. km area is analyzed for the study

The KSC Network

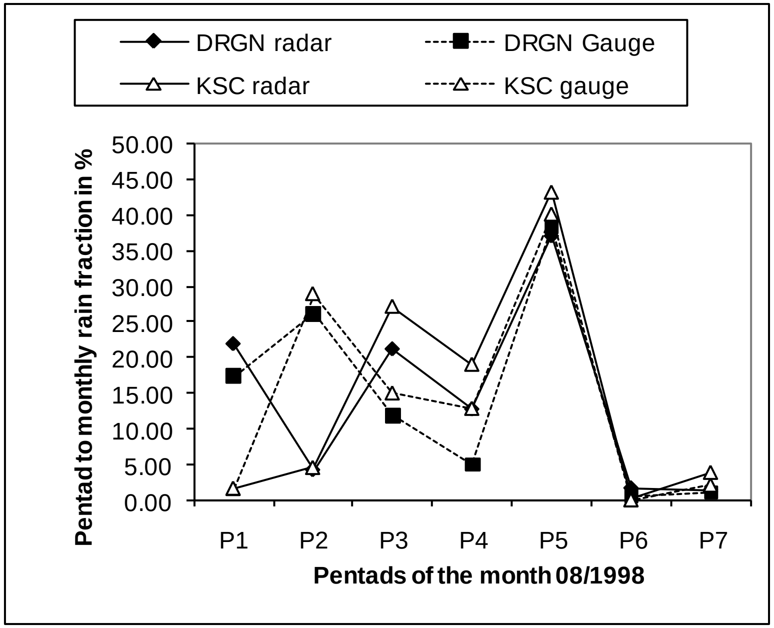


Located approximately 60 km N of KMLB

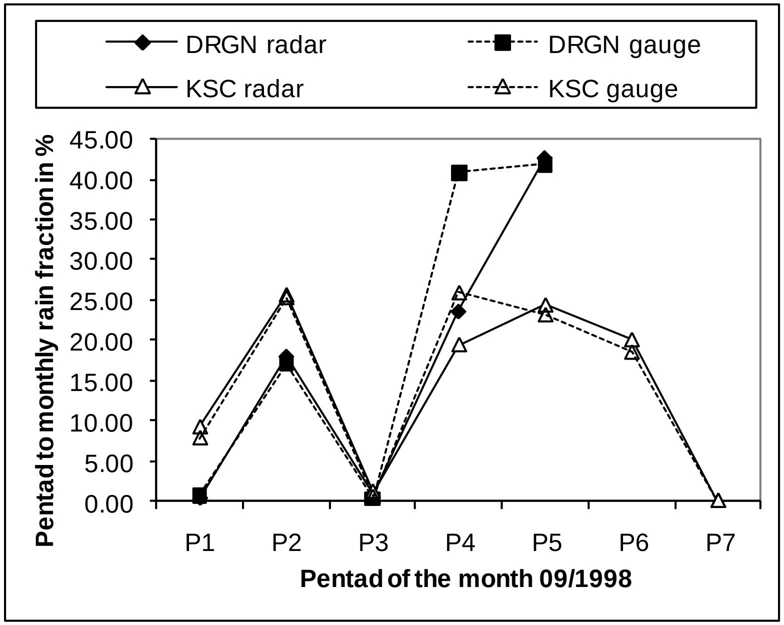
The lowest elevation beam is approximately at 719 m height above ground over KSC.

Total 28x36 sq. km area is analyzed

Time Series for Pentad Fraction

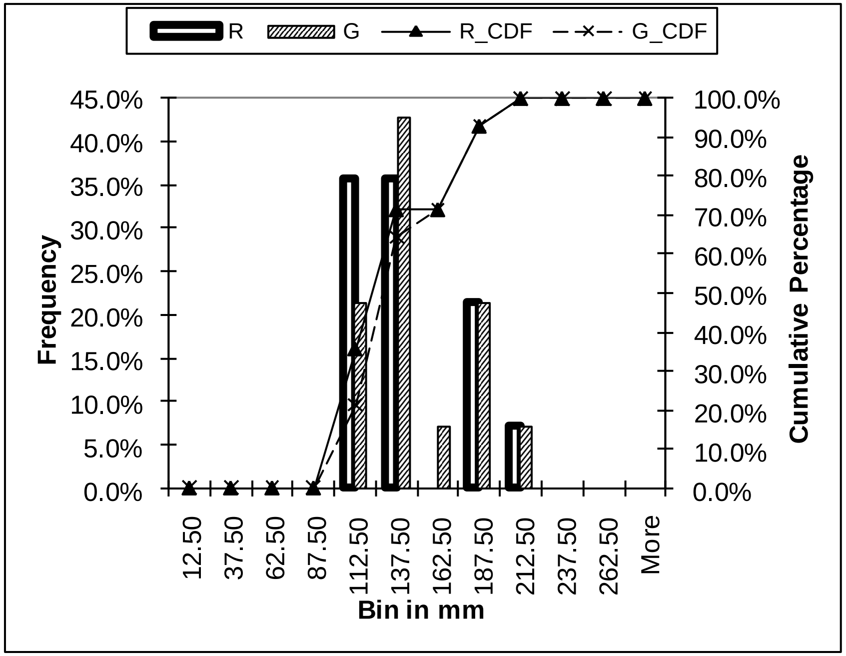


August 1998

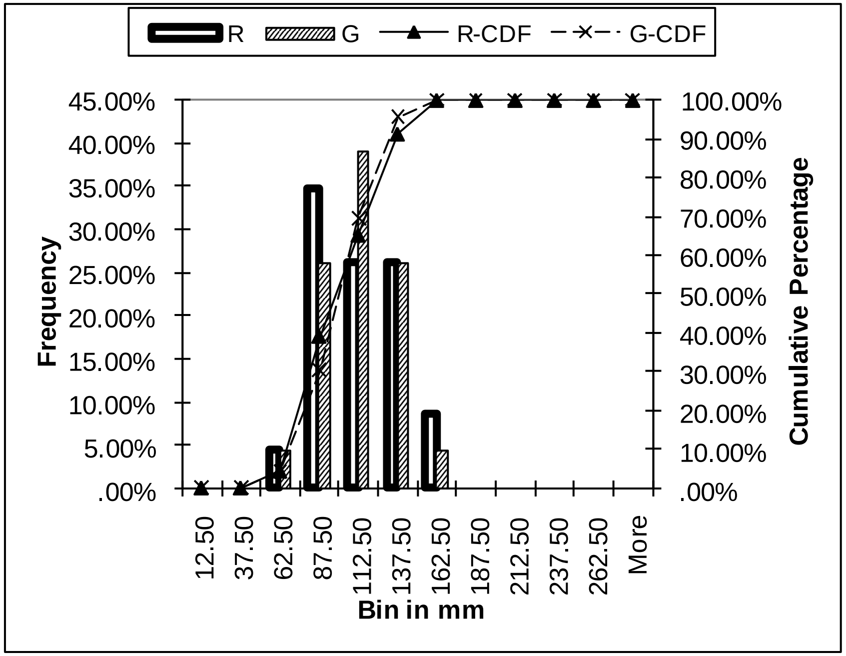


September 1998

Histogram & CDF for 08/98

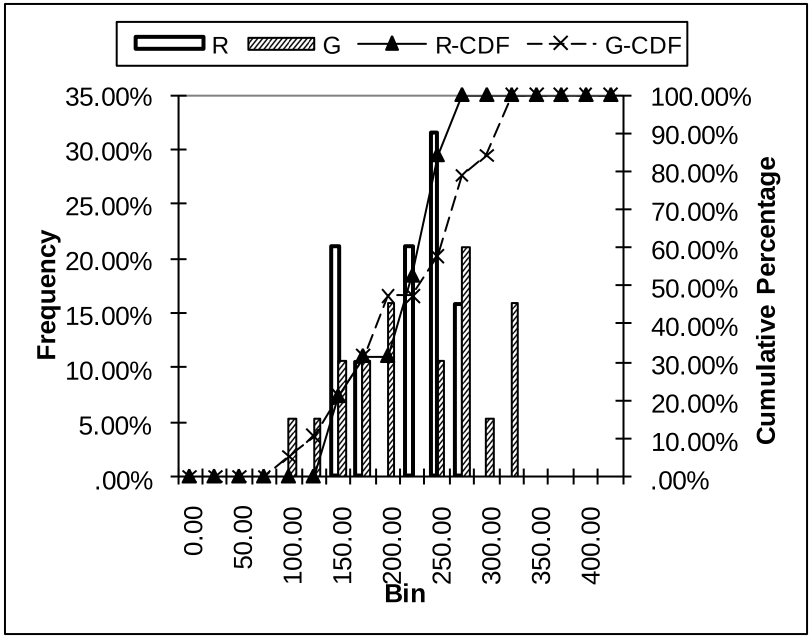


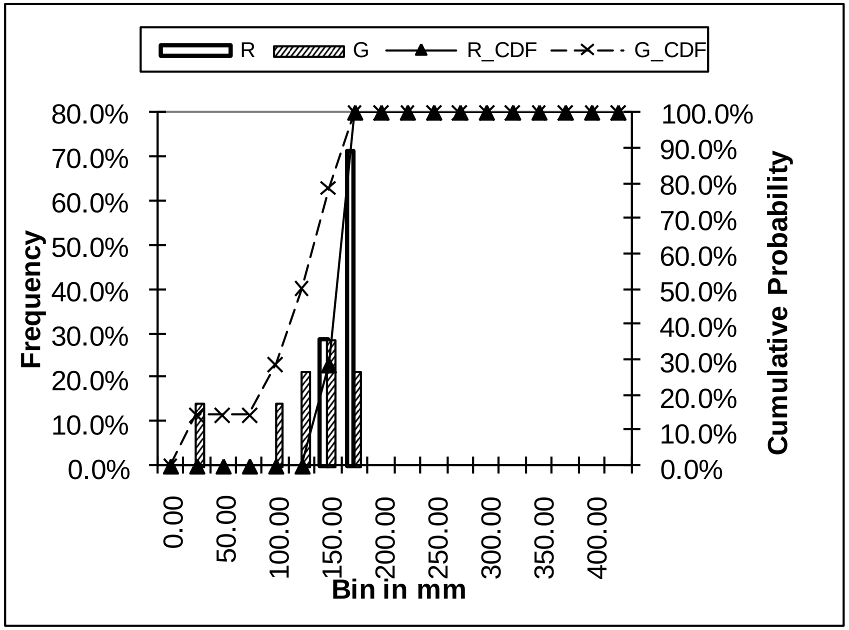
Over KSC Network



Over DRGN Network

Histogram & CDF for 09/98





Over KSC Network

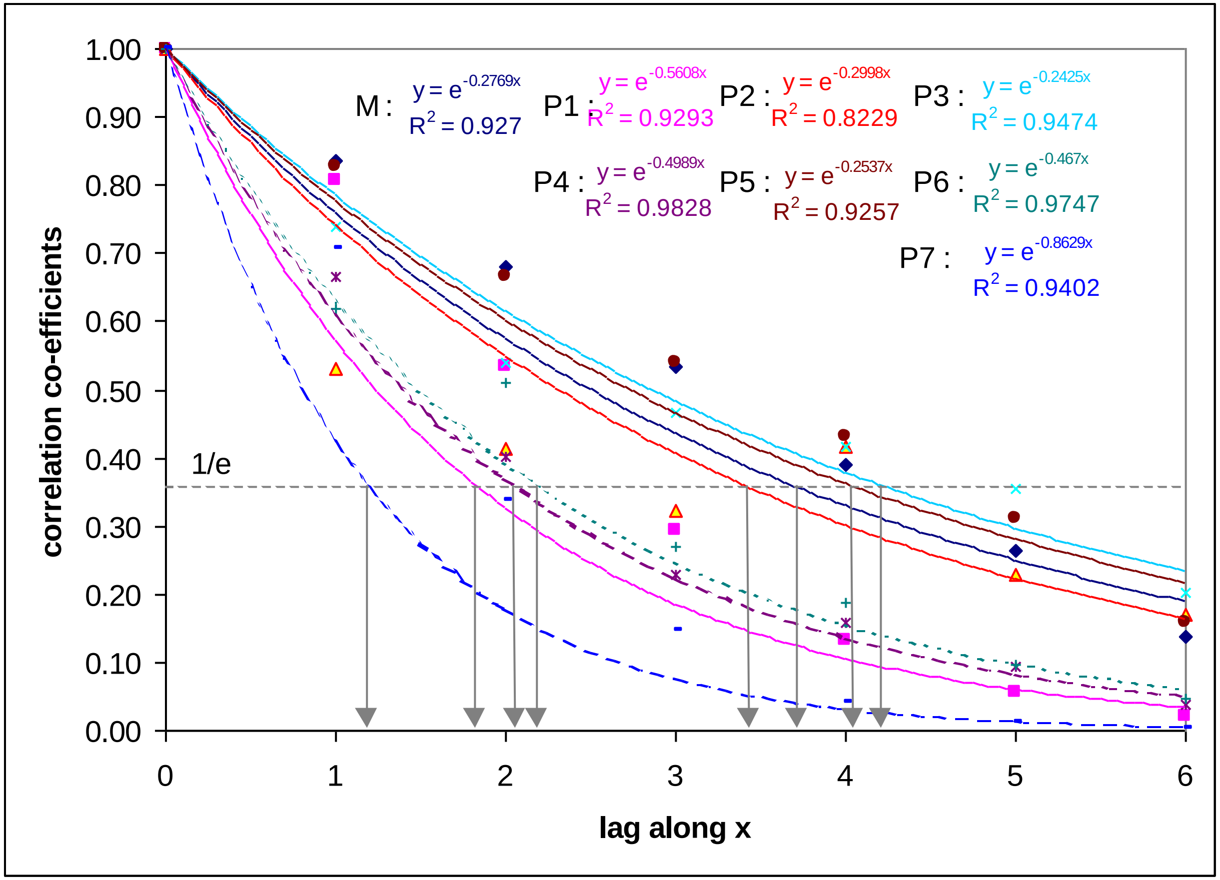
Over DRGN Network

- Statistical significance test: *averages are matching but the variances are not*

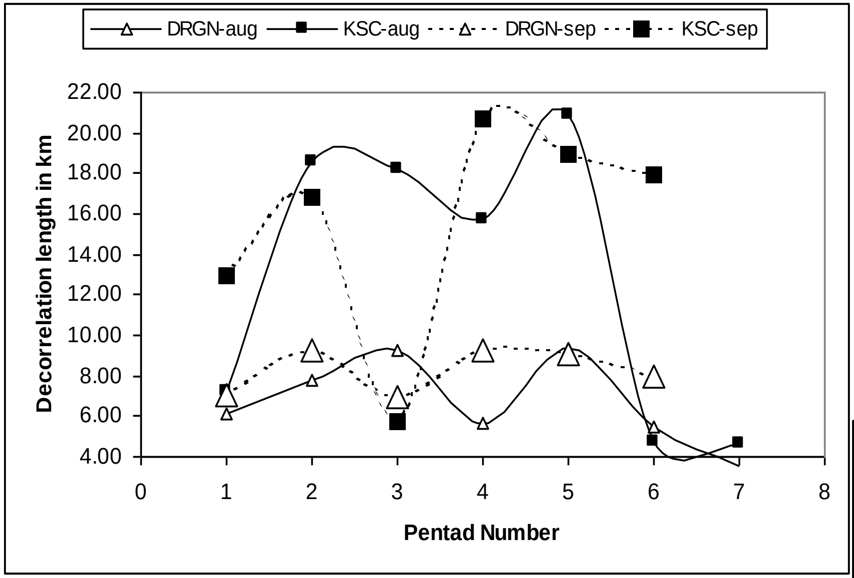
De-correlation: method

- Perform spatial auto-correlation of the observed rainfall.

- $d_x = 2 * lag_x$
- $d_y = 2 * lag_y$
- $d = \sqrt{(d_x^2 + d_y^2)}$



De-correlation : result



For Radar

Monthly d:

DRGN, 08/98 : 9.01 km

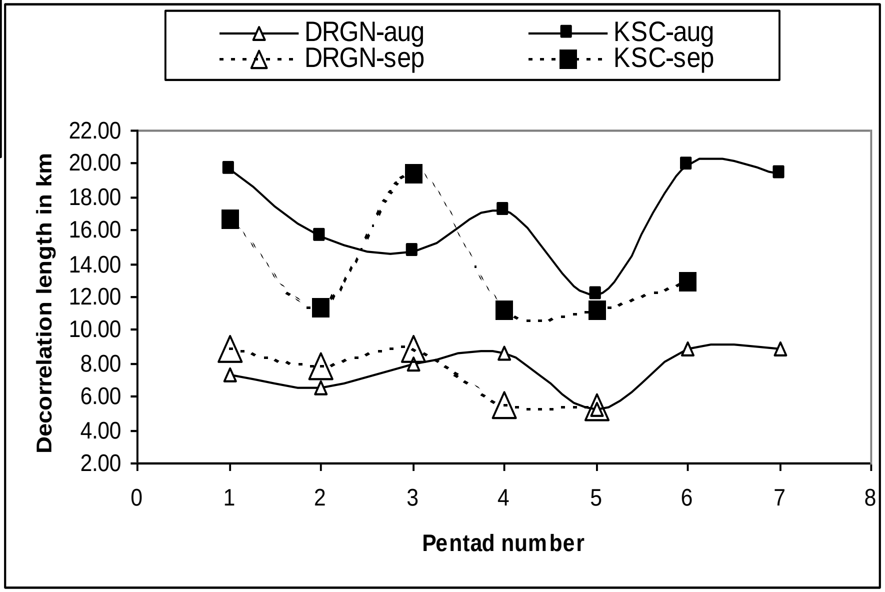
DRGN, 09/98: 9.70 km

Monthly d:

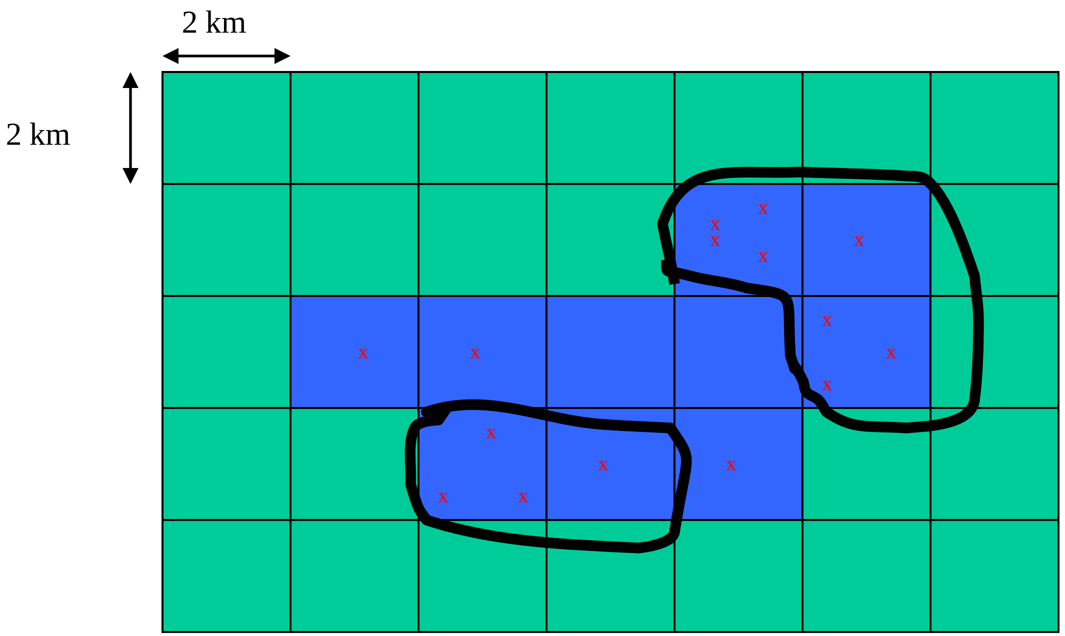
KSC, 08/98 :19.10 km

KSC, 09/98: 20.49 km

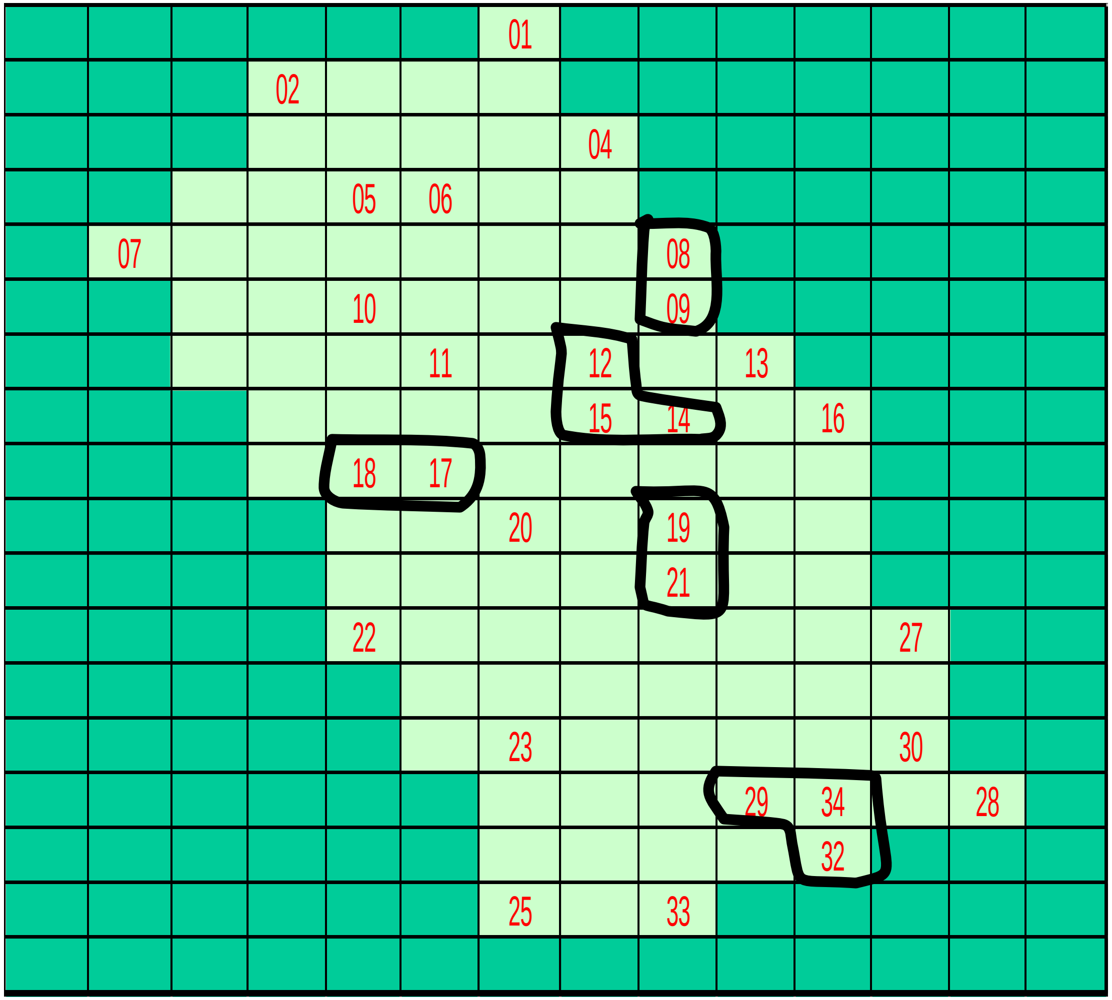
For Gauge



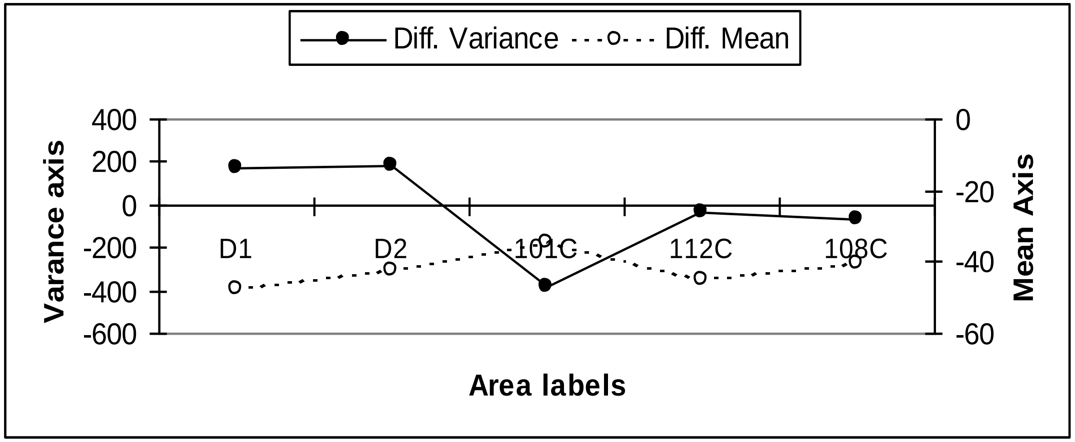
DRGN Sub Areas



KSC Sub Areas

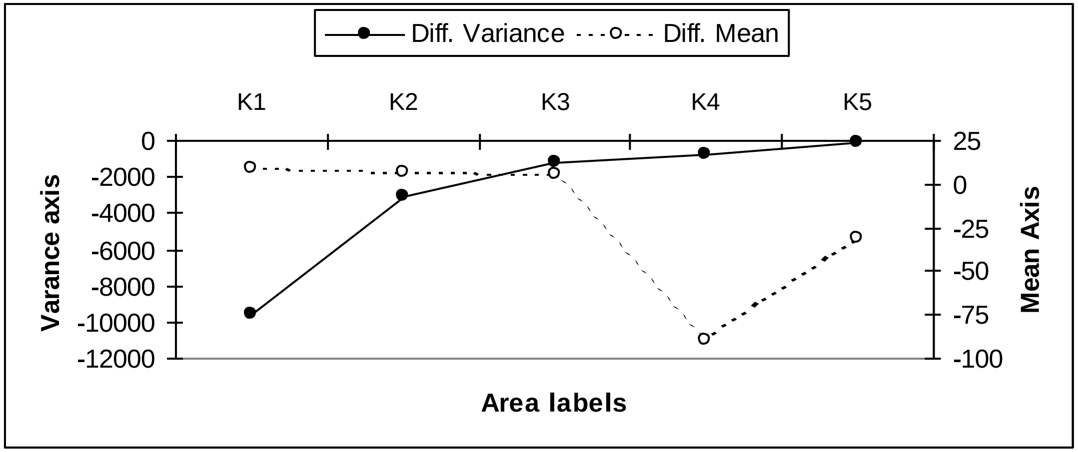


Sub-network scale variation



DRGN

08/98



KSC

08/98

Contribution of area-point difference to R-G difference variance

Table 3.7 Percentage contribution of area-point difference to R-G difference variance

	Whole Network	D1	D2	101C	112C	108C
P1	18.84	10.74	9.07	11.06	11.06	11.06
P2	4.03	3.32	1.02	11.06	11.06	11.06
P3	14.72	8.11	18.01	11.06	11.06	11.06
P4	4.66	9.34	14.88	11.06	11.06	11.06
P5	2.54	9.02	5.57	11.06	11.06	11.06
P6	22.48	8.83	10.11	X	11.06	11.06
P7	10.79	12.67	0.48	11.06	11.06	X

Redundancy required?

Month	Cluster #	R in mm	Gauge ID	G in mm
Aug-98	101C	132.14	101a	173.90
			102	140.10
			103	165.20
			101b	186.50
	112C	106.93	112	146.00
			114	157.50
			115	152.90
	108C	170.65	108a	220.80
			108b	207.30
			108c	205.90
Sep-98	101C	150.53	101a	165.50
			102	175.50
			103	6.40
			101b	164.10
	112C	171.75	112	165.80
			114	175.30
			115	172.30
	108C	138.13	108a	143.60
			108b	14.50
			108c	123.50

TEFLUN-B

Site	Radar Estimate	Gauge ID	Gauge Estimate	R-G	Average R-G	Variance(G
Roi	253.84	207	257.90	-4.06	34.56	9141.46
Namur		312	268.80	-14.96		
		313	257.10	-3.26		
		314	250.20	3.64		
		315	24.50	229.34		
		316	257.20	-3.36		
Illegini	180.76	208	59.90	120.86	97.66	1076.48
		311	106.30	74.46		
Legan	184.56	209	4.60	179.96	91.21	15753.13
		306	182.10	2.46		
RMI 102	401.52	102	0.00	401.52	220.92	65232.72
		111	361.20	40.32		

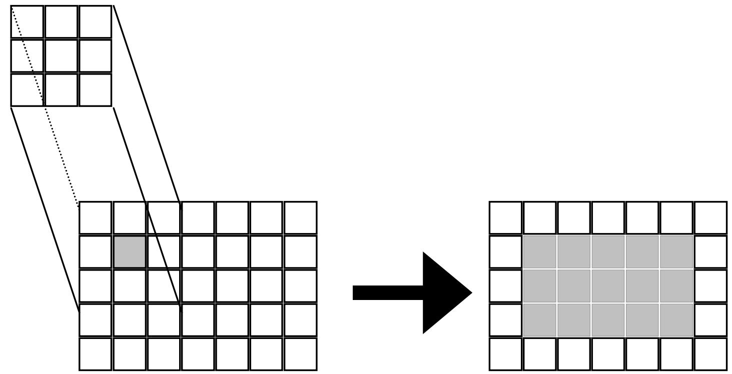
KWAJEX

Spatial Matching

- Used a sliding window method.

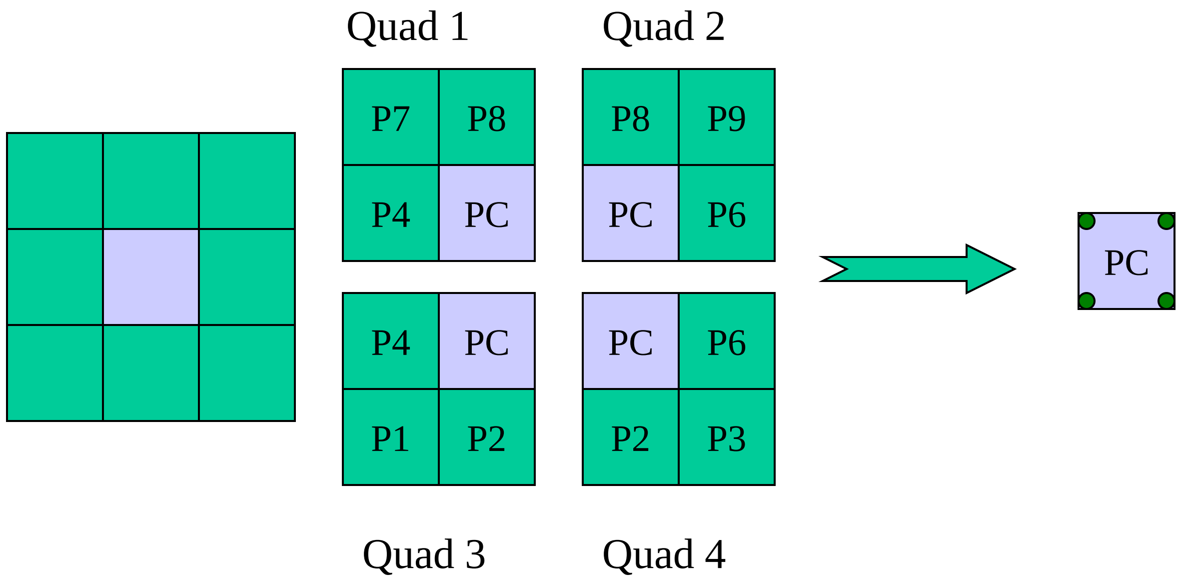
- Three different Smoothing, namely, quad smoothing, median filter and trimming filter, is used.

- Lagrange Polynomial interpolation is also used: magnification effect.



- A five point evaluation of each method is carried out.

Quad Smoothing (QS)



1/20	2/20	1/20
2/20	8/20	2/20
1/20	2/20	1/20

Median and Trimming

- Median Filter (MF): Substitute the central pixel value by the median of the 9 pixel values.

- Trimming Filter: (TF)
  – Sort the 9 values.
  – Trim the two highest and 2 lowest values.
  – average the the central subset of five elements.
  – Substitute the central pixel by this average.

Interpolation method

Lagrange polynomial (LP) interpolation in two dimension

First interpolate along x:

$I_i(x,y_i)= \Sigma_n R(x_n, y_i)*L_n(x)$;

$L_n(x) =[\Pi_{m\neq n}(x-x_m)]/[\Pi_{m\neq n}(x_n-x_m)]$;

Next interpolate along y:

$R(x,y)= \Sigma_i I(x, y_i)*L_i(y)$;

$L_i(x) =[\Pi_{m\neq i}(y-y_m)]/[\Pi_{m\neq i}(y_i-y_m)]$;

Evaluation Criterion

- Probability of yielding better match.
- Difference of mean between radar and gauge.
- Difference in variance between radar and gauge.
- Average R/G over each network.
- Bulk R/G with all networks.

Result: The LP Method is giving best comparison

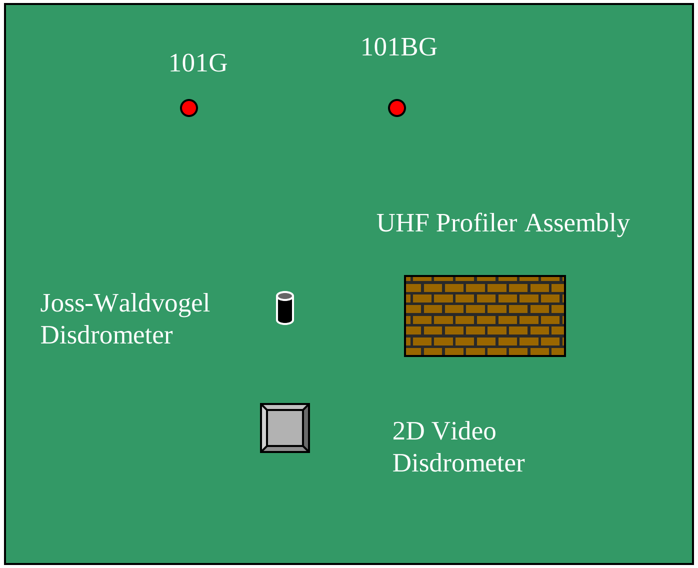
Improvement in KWAJ

Table 4.3 Comparison of bulk radar to gauge monthly estimates for KWAJ using quality gauge data

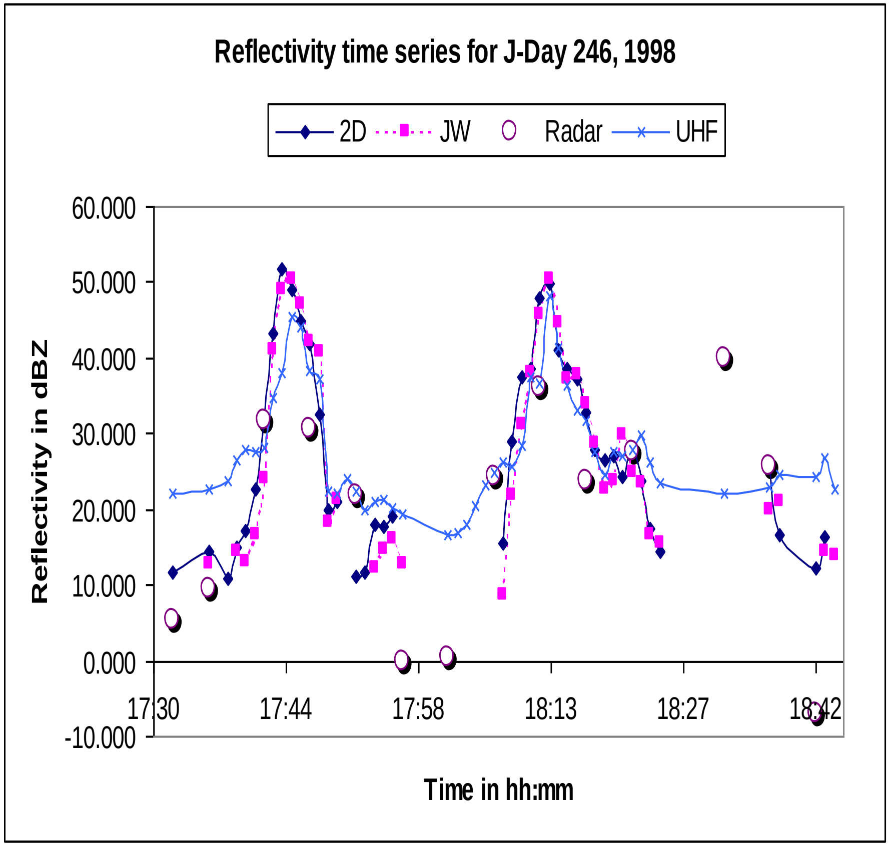
Month	Bulk G	Bulk R from 'O'	Bulk R from 'LP'	O/G	LP/G
08/1998	251.18	212.08	222.42	0.84	0.89
09/1998	344.68	325.98	327.65	0.95	0.95
11/1998	447.29	367.40	362.80	0.82	0.81
06/1999	295.91	364.43	346.12	1.23	1.17
07/1999	767.57	718.01	784.33	0.94	1.02
08/1999	1086.96	1069.72	1070.18	0.98	0.98
09/1999	899.45	720.80	742.58	0.80	0.83

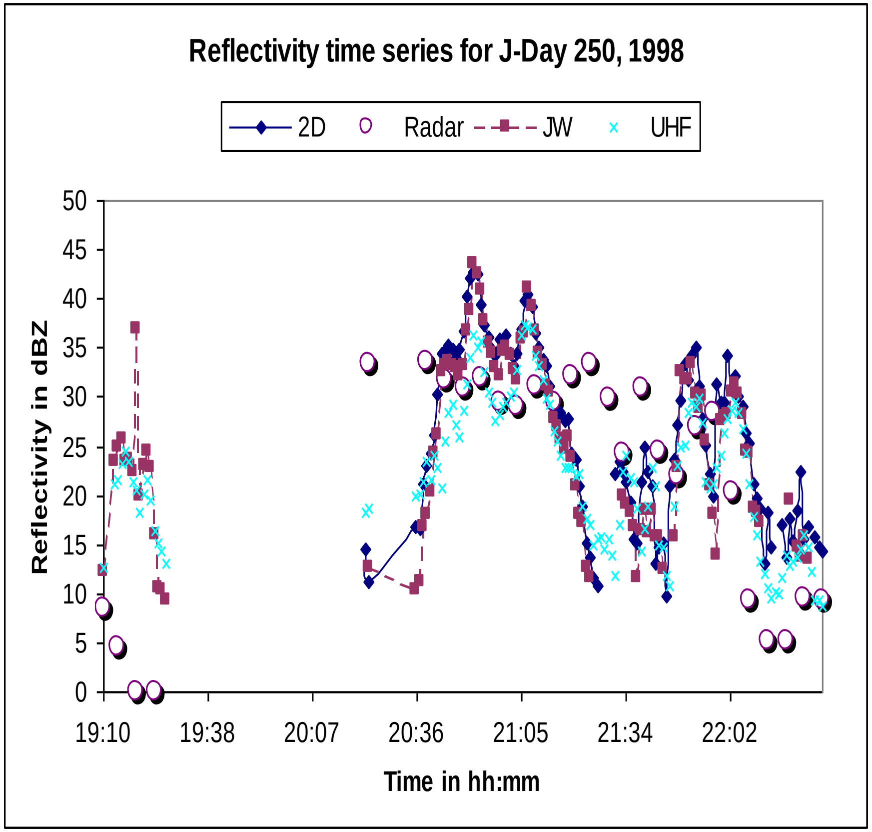
TEFLUN-B Master GV Site

- Located Approximately at 28.13N, 81.01W in the DRGN NETWORK at Triple-N Ranch, Holopaw, Florida. Also called the 101 Gauge site.
- Relative arrangements of other instruments that are being compared with gauge and NEXRAD are shown below.

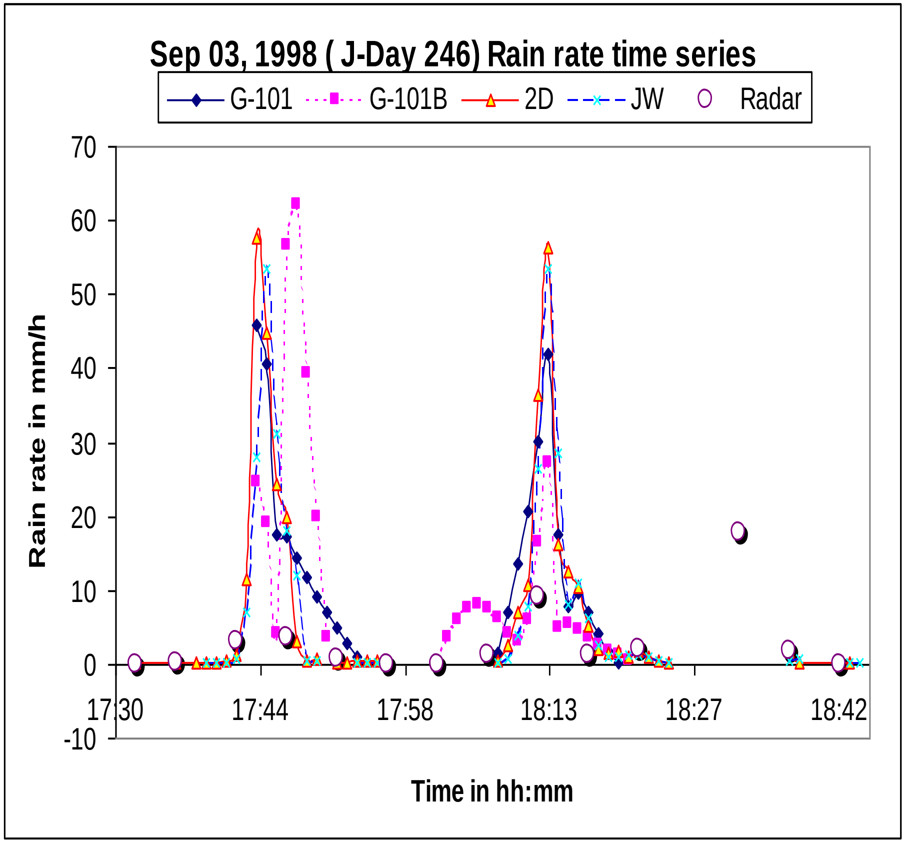


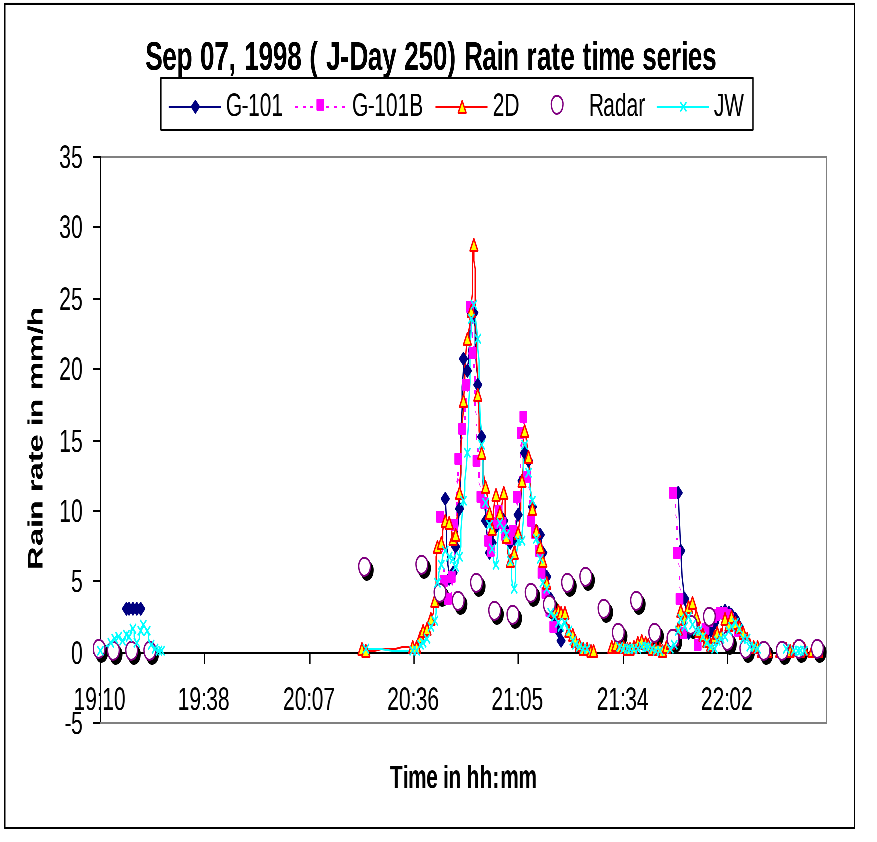
Reflectivity time series





Rain rate time series





Temporal matching

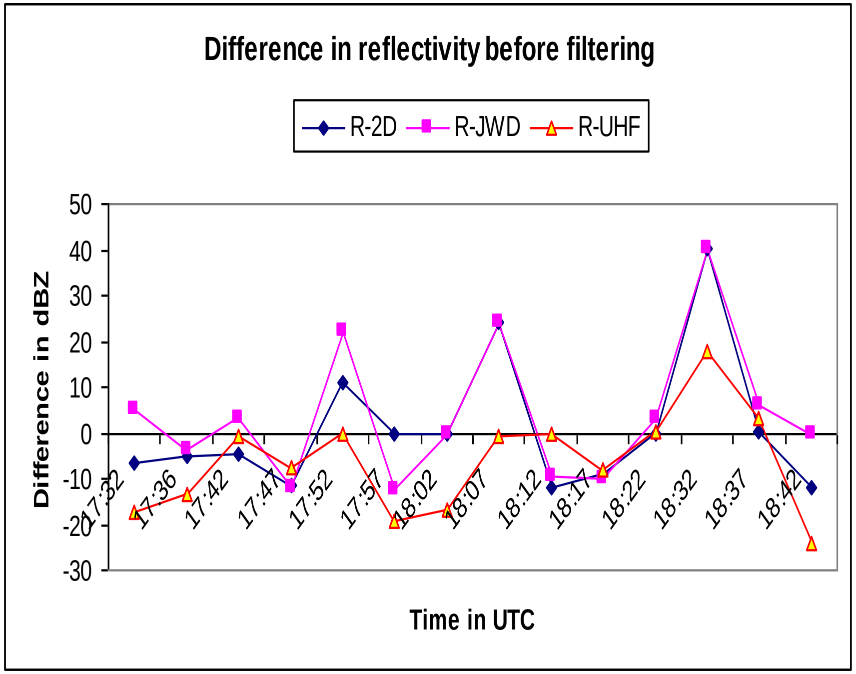
- Three Methods examined:
  - Resample all surface observation at radar VOS time.
  - Average the surface observation in a five minute window around radar VOS time.
  - Take median of the five minute window around radar VOS time.

Evaluation

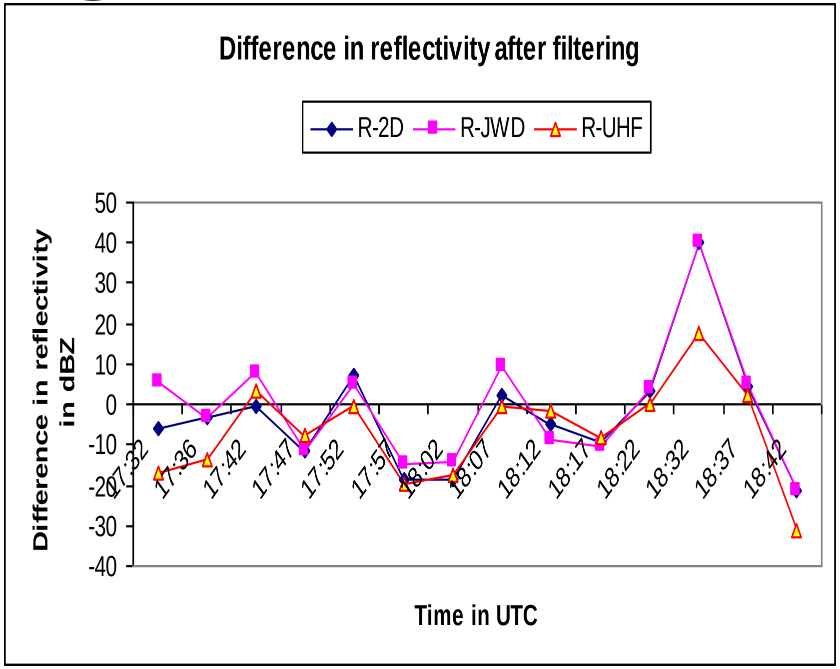
- Statistical significance test for mean and variance are carried out to characterize better matching of radar to surface.
- Other three factors for evaluation are:
  - Correlation between two sets of estimate.
  - Difference of Mean.
  - Difference of variance.

Result: The Median Filter yields best comparison.

Result of combined spatial-temporal filtering



Before



After

Conclusions

Q. What is the observed spatial variability of precipitation?

Ans.: The Spatial Variability depends upon the type and duration of precipitation. It varies from region to region and in monthly time scale the de-correlation length is of the order of 10-20 km.

Conclusions

Q. Does the Spatial Variability affects radar rain retrieval?

Ans.: Yes.

Q. How does the point-area difference affect radar calibration?

Ans.: From about 11% to as high as 19%

Conclusions

Q. Do we need dual Z-R?

Ans.: Depends on what product we are interested in. For area average rainfall over a long time, both single and dual Z-R will yield similar result.

Q. Is redundancy of gauge observation required before calibration?

Ans.: Yes, the gauges frequently give erroneous observations.

Conclusions

Q. What is the best matching method found?

Ans.:

Spatially- Interpolate the coarse resolution data exactly over the finer resolution grid.

Temporally - apply median filter to the fine resolution data with a five minute window centered around the coarse observation grid.

Usefulness

- Can be used for any multi-sensor calibration /validation studies.

Related Publications