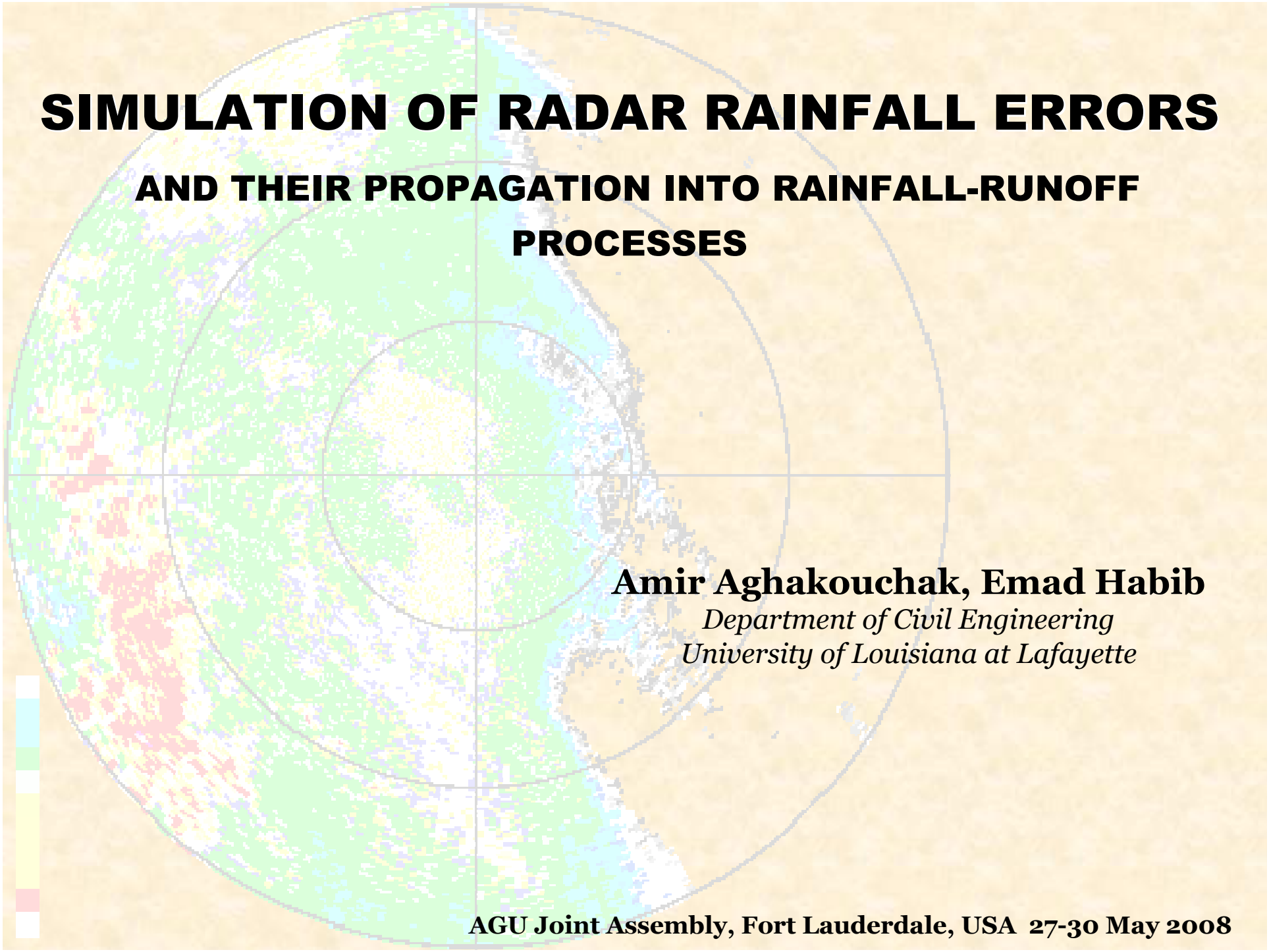
SIMULATION OF RADAR RAINFALL ERRORS

AND THEIR PROPAGATION INTO RAINFALL-RUNOFF PROCESSES



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AGU Joint Assembly, Fort Lauderdale, USA 27-30 May 2008

Motivation

Different types of errors associated with the radar rainfall measurements:

Physical Biases

- Ground clutters, beam broadening, beam blockage

Measurement Biases

-Inappropriate Z-R relationship

Random Errors

- Temporal and spatial sampling error, random variability in vertical profile, calibration and quantization of data, etc.

Content

-Characteristics of error

- -Spatial dependencies
- -Temporal dependencies
- -Stochastic properties
- -Probability distribution

- Simulation of random error

- -Monte Carlo simulation
- -Monte Carlo with Cholesky decomposition

- Generating possible realizations of true rainfall

- Hydrograph ensemble

Study Area

Goodwin Creek Watershed

Location: MS, USA

Area: 5200 Acers

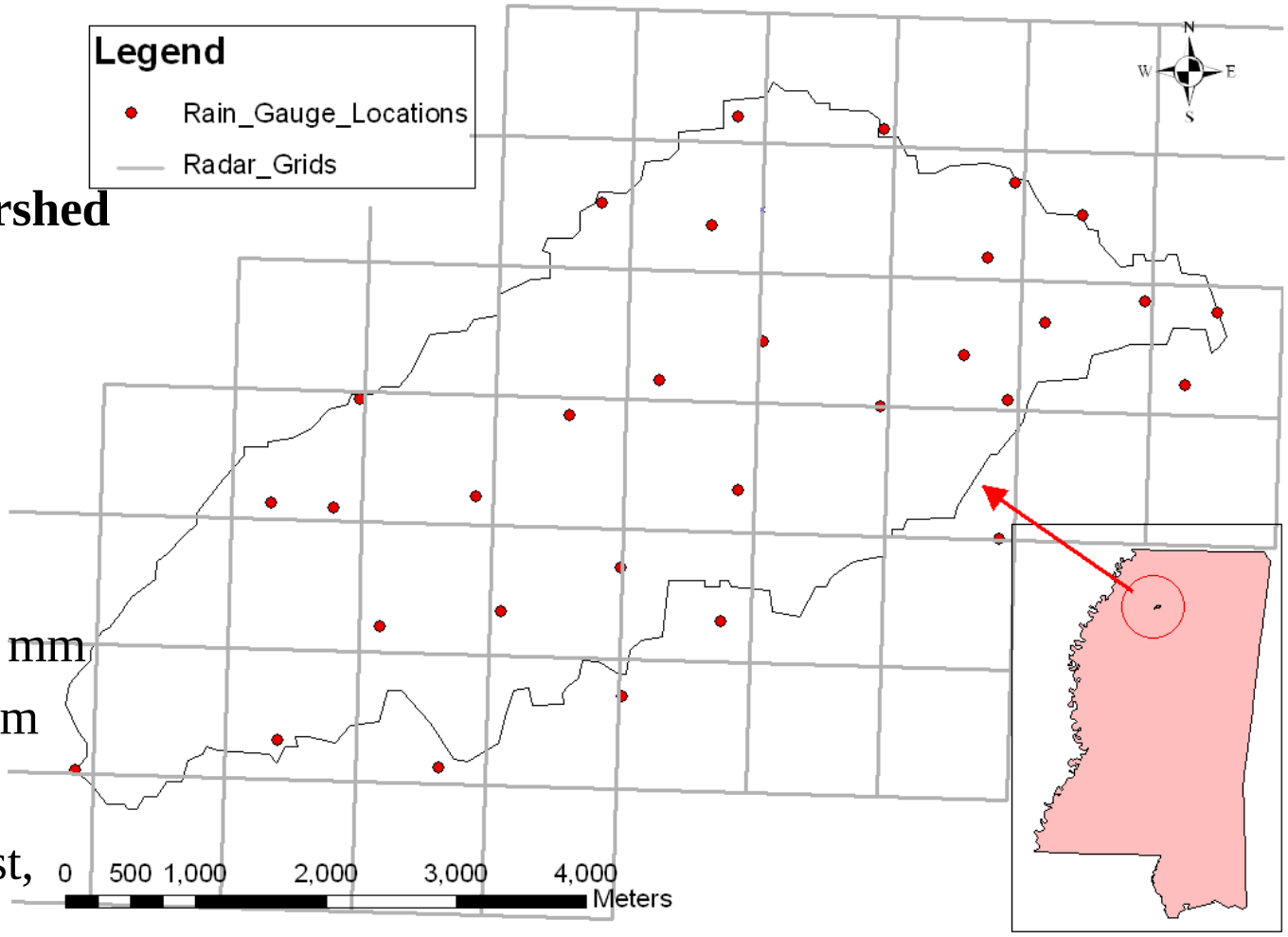
32 Rain Gauges

Annual Rainfall: 1440 mm

Annual Runoff: 145 mm

Soil: Silt loam silt clay

Landuse: Pasture, forest, cultivated land



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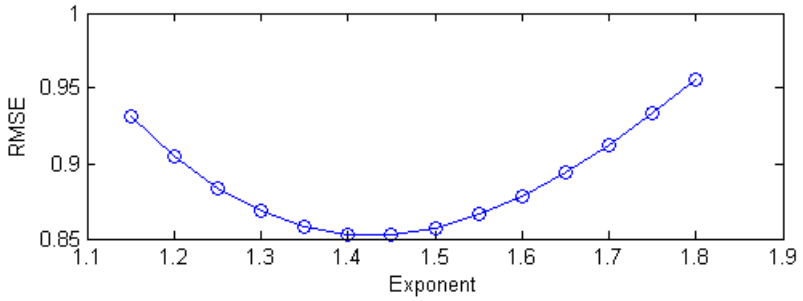
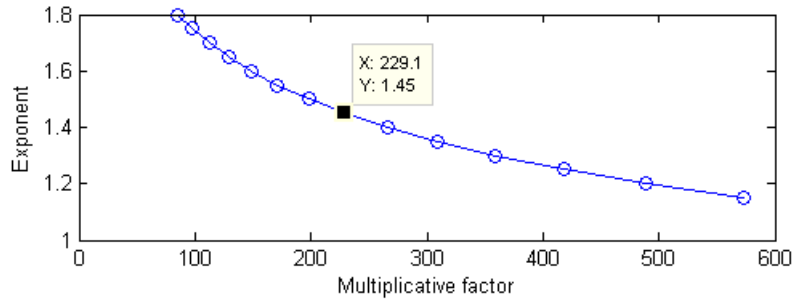
Measurement Biases



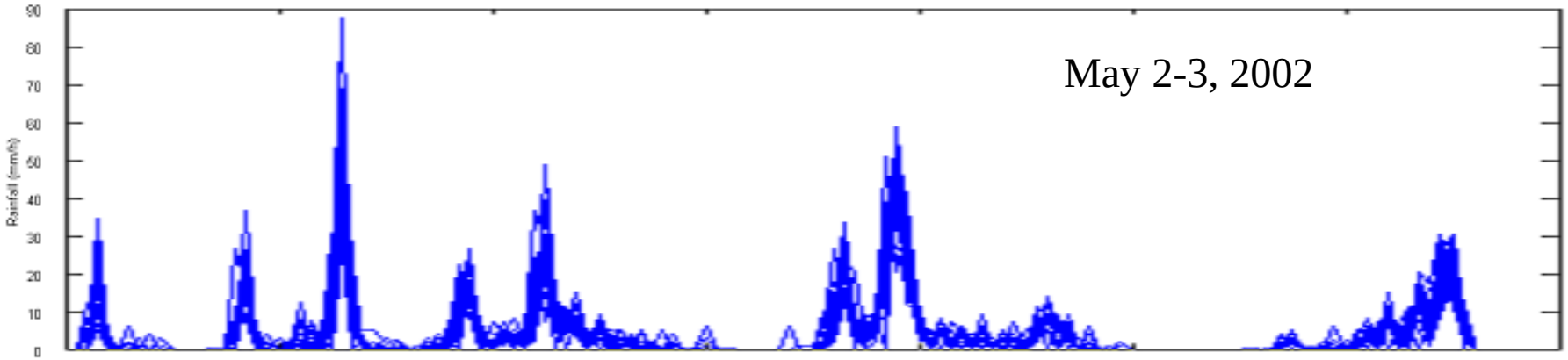
$$A = \left[\frac{\sum_{j=1}^{m} Z_j^{1/b}}{\sum_{j=1}^{m} R_j} \right]^b$$

$$RMSE = \sqrt{\frac{1}{m-2} \sum_{j=1}^{m} \left[\frac{R_j - (Z_j / A)^{1/b}}{R_j} \right]^2}$$



$$Z = 229.1 R^{1.45}$$

$$e = \frac{R}{G}$$



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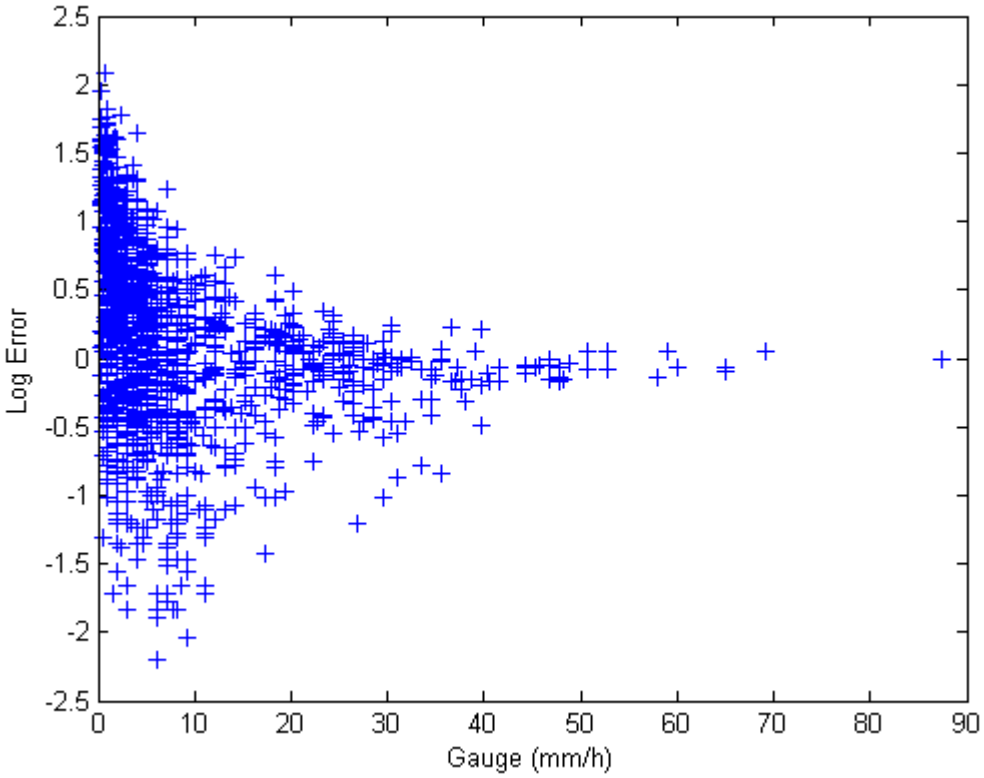
Error Characteristics



Variance of radar error seems to reduce with the magnitude of radar.

Error Characteristics – Probability Distribution

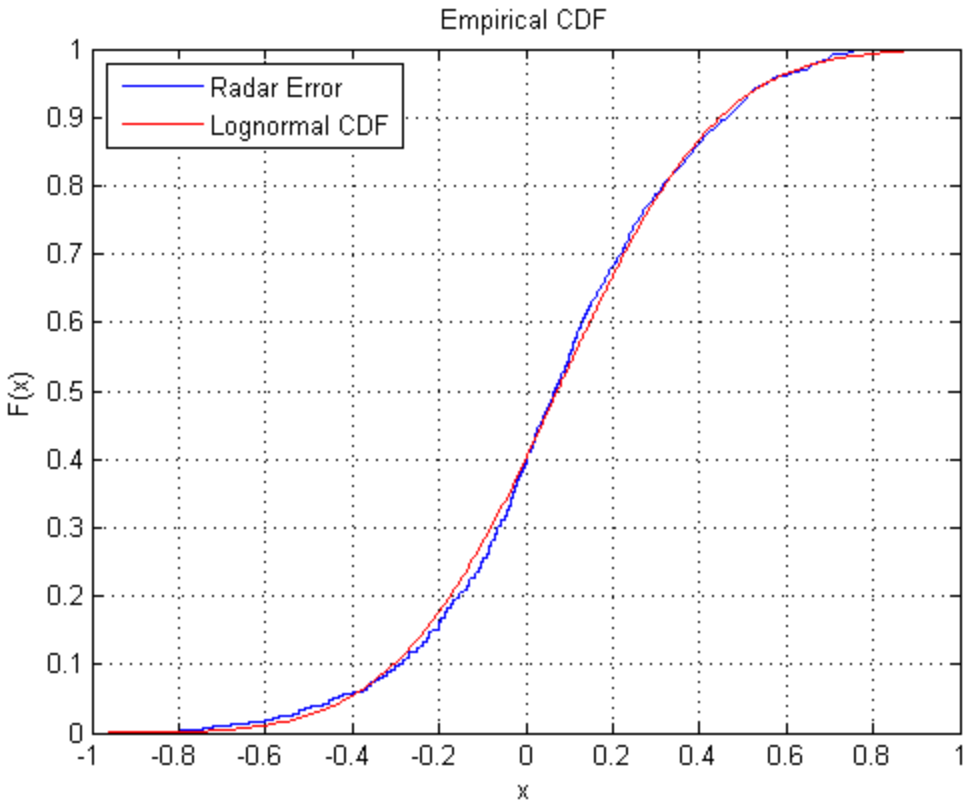
Kolmogorov-Smirnov Test

-Normal

-Lognormal

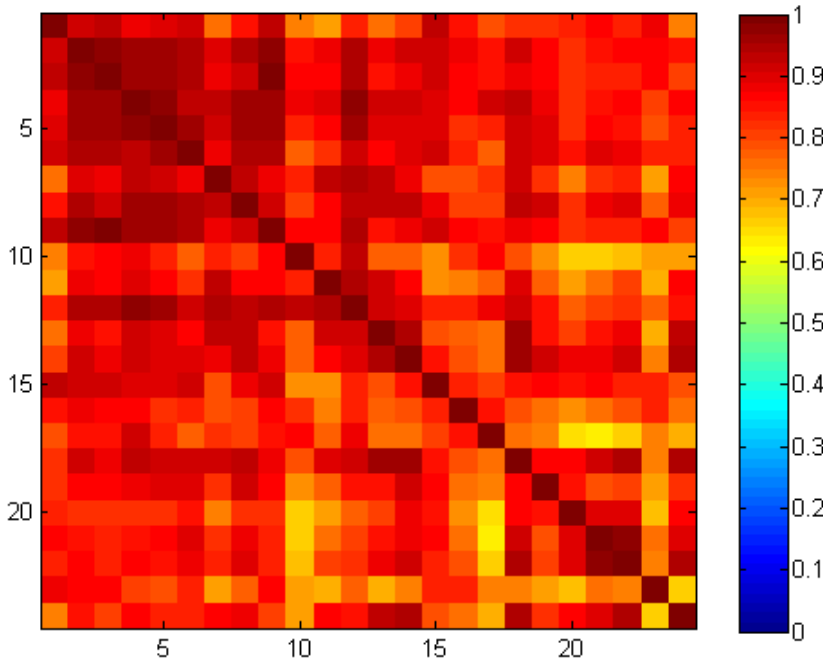
-Weibull

-Gamma

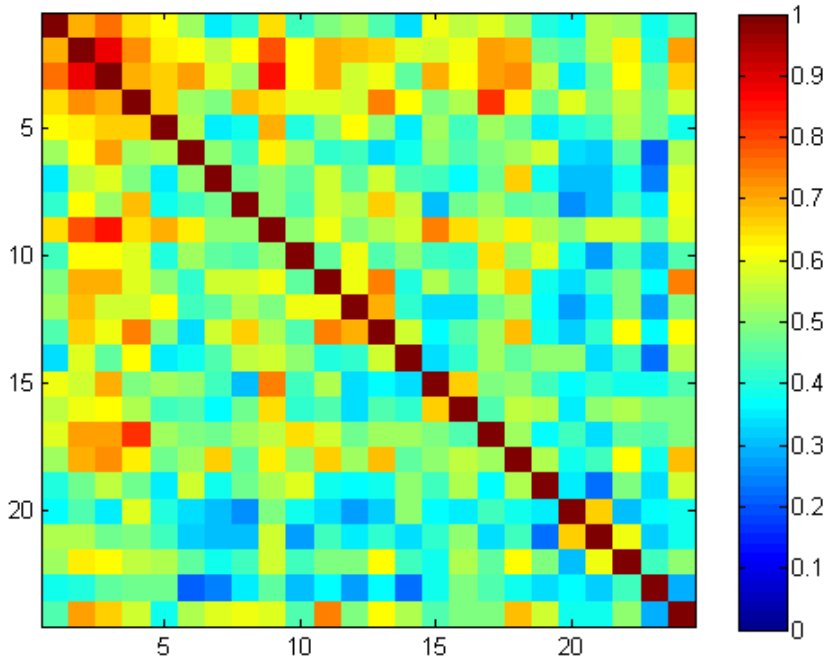


The hypnosis could not be rejected for LOGNORMAL distribution.

Error Characteristics – Spatial Dependencies



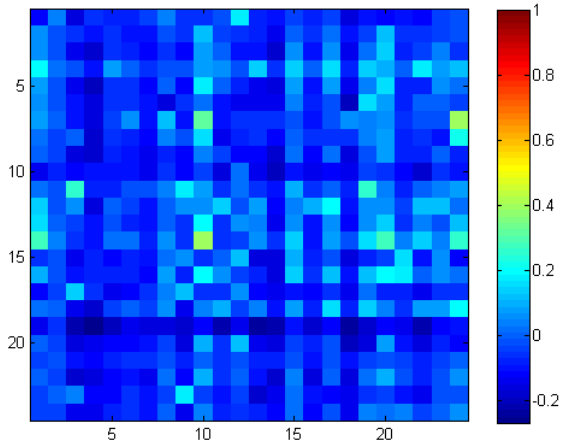
Radar Rainfall Corr. Matrix



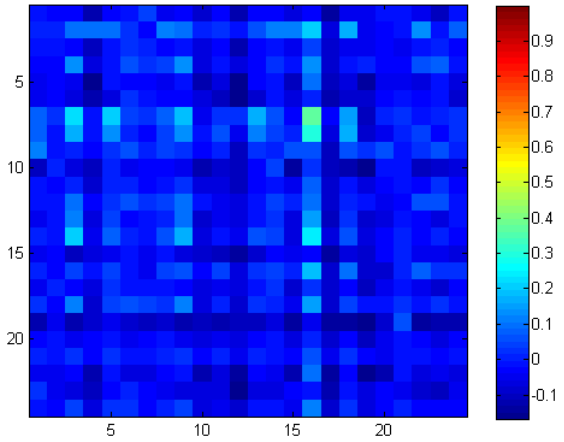
Radar Error Corr. Matrix

Spatial dependencies of radar error fields are NOT negligible

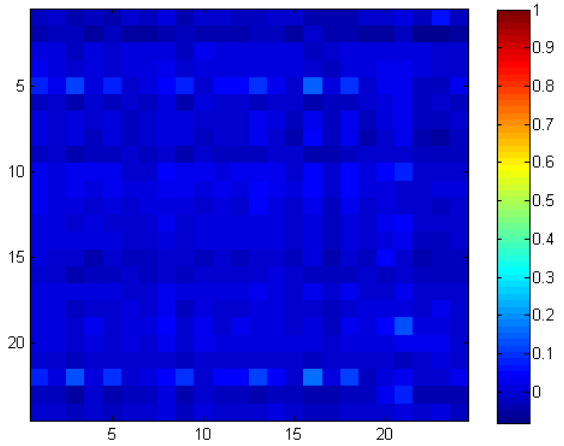
Error Characteristics – Temporal Dependencies



Time Lag: 15min



Time Lag: 30min



Time Lag: 45min

Temporal Auto-correlation Matrix

Auto-correlation of each pixel with itself and all other pixels

Temporal dependencies of radar error fields seem to be negligible

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Simulation Scenarios

CASE 1:
- Variance of radar error is independent of radar magnitude.
-No spatial correlation in simulated error fields.

$$\begin{cases} Var \neq f(R_r) \\ e \propto NotCorr. \end{cases}$$

CASE 2:
- Variance of radar error is NOT independent of radar magnitude.
- No spatial correlation in simulated error fields.

$$\begin{cases} Var = f(R_r) \\ e \propto NotCorr. \end{cases}$$

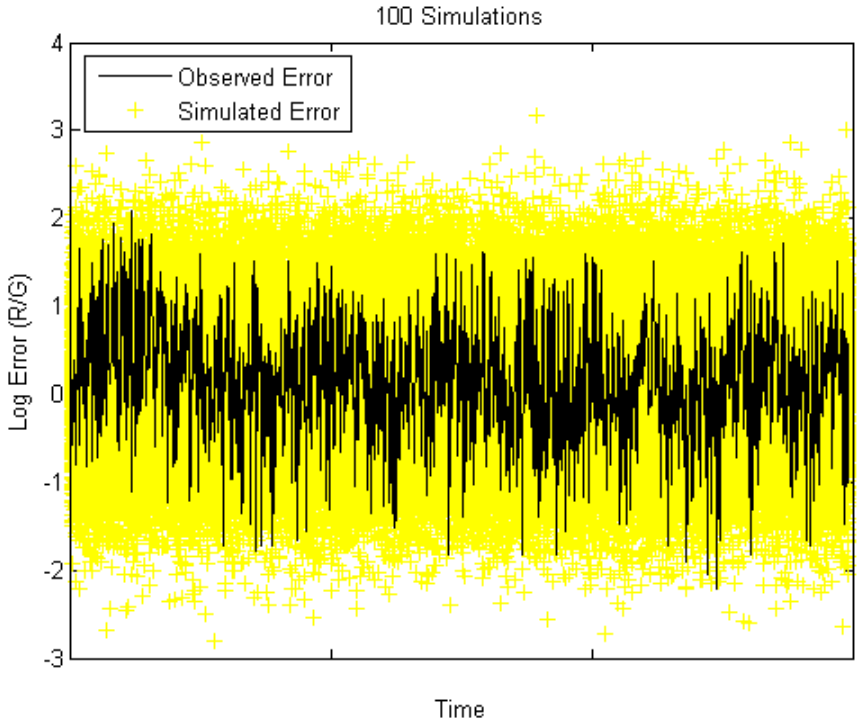
CASE 3:
-Variance of radar error is NOT independent of radar magnitude.
- Spatial correlation in simulated error fields is preserved.

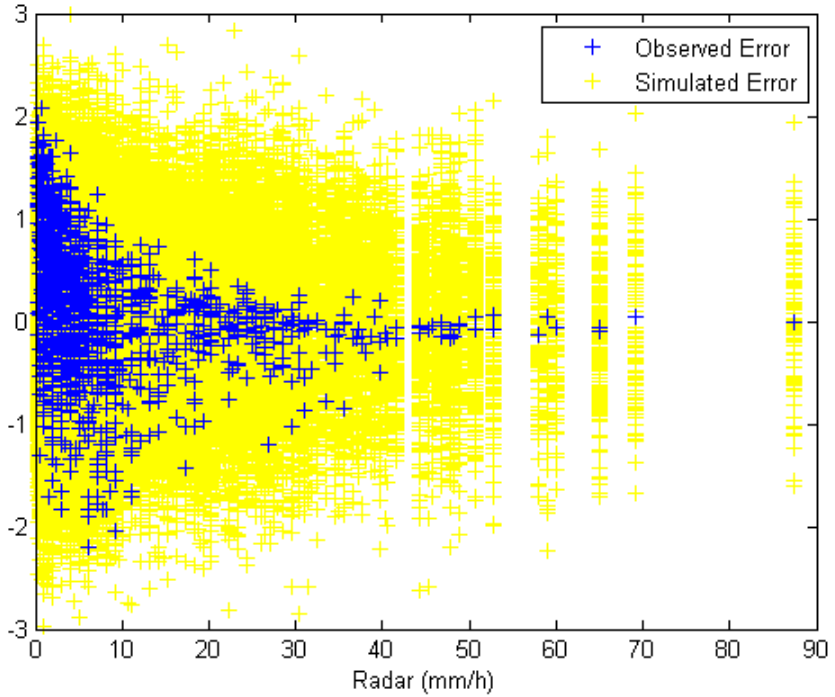
$$\begin{cases} Var = f(R_r) \\ e \propto Corr. \end{cases}$$

Simulation of Radar Error - Case 1

$$\begin{cases} Var \neq f(R_r) \\ e \propto NotCorr. \end{cases}$$

Simulated errors (yellow dots) do NOT follow the trend of observed errors (blue plus sign)



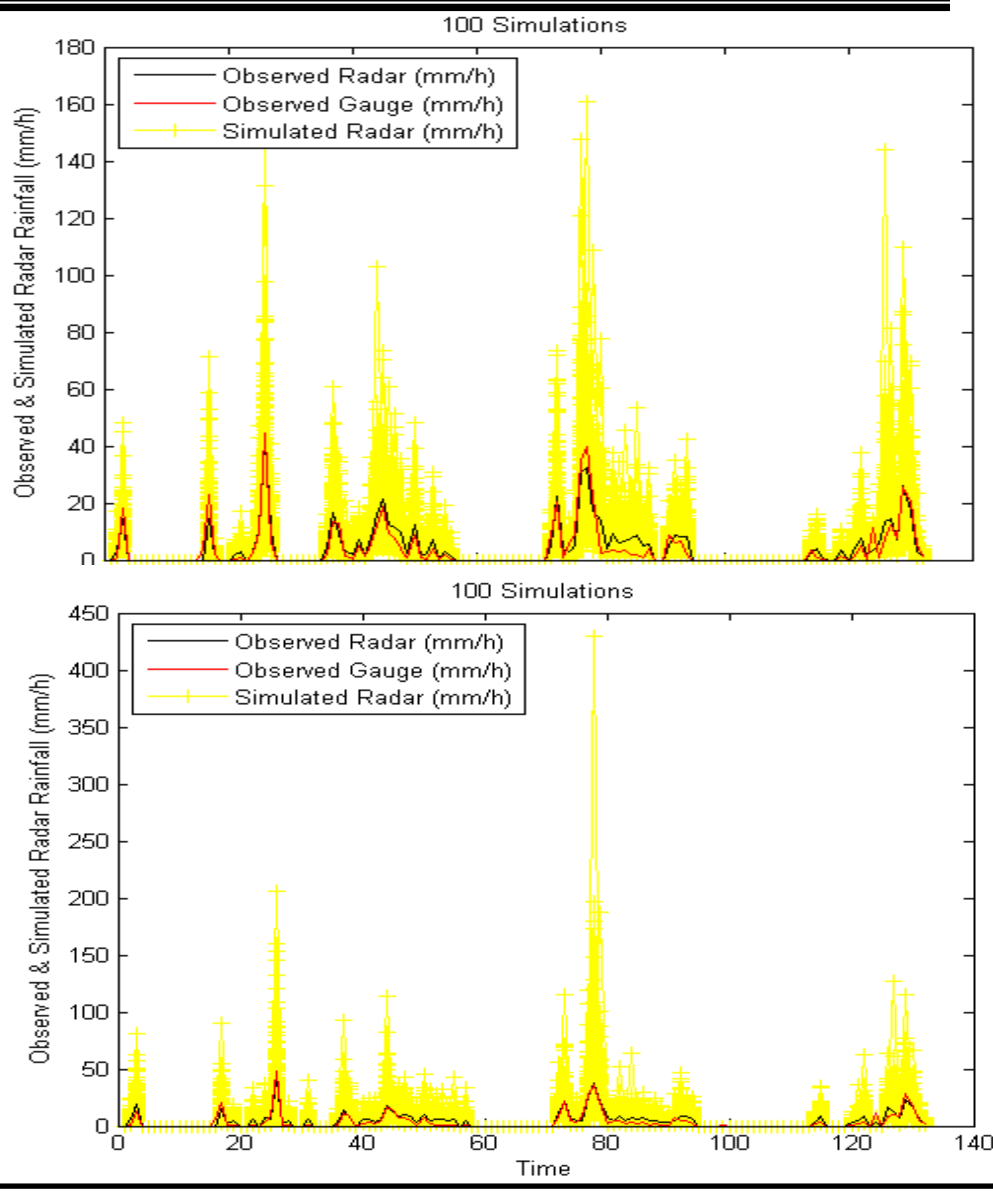


Simulation of Radar Error - Case 1

$$\begin{cases} Var \neq f(R_r) \\ e \propto NotCorr. \end{cases}$$

No conditioning on error

large errors may imposed on a large magnitudes of radar and result in unrealistically large simulated radar data.



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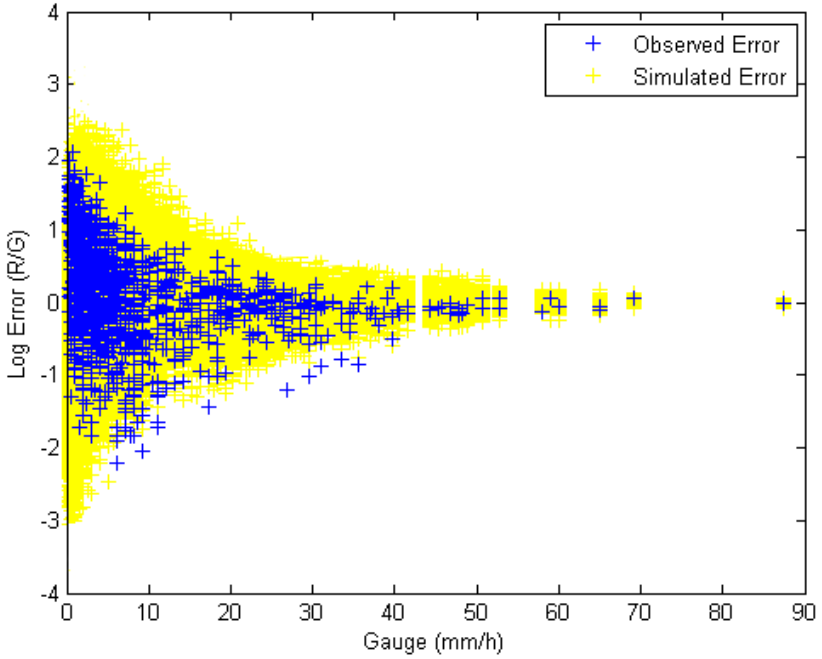
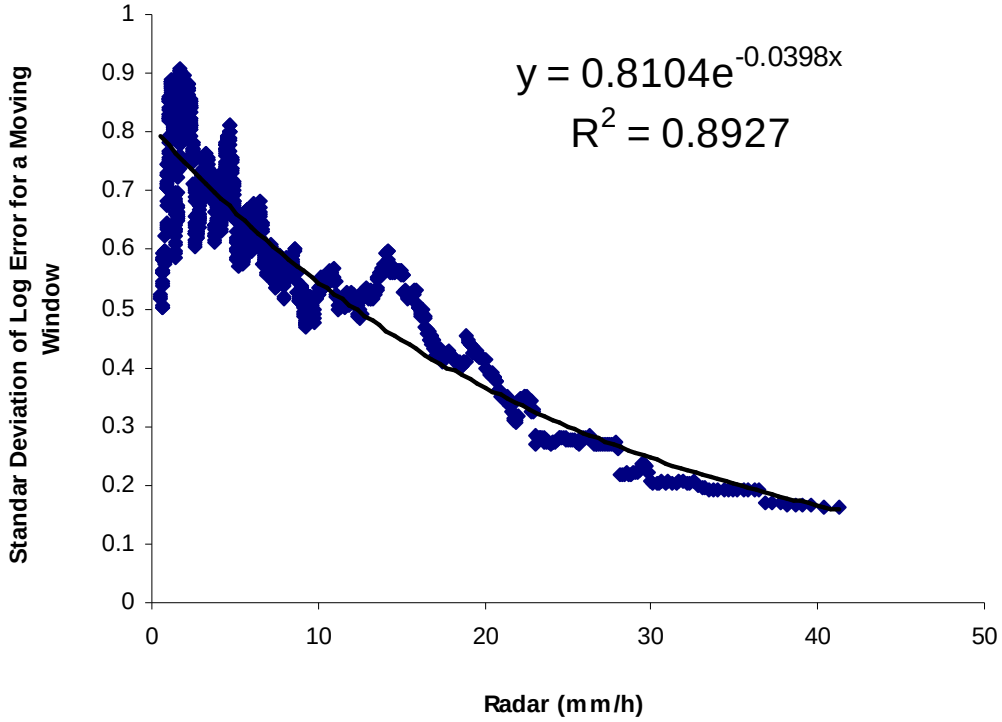
Simulation of Radar Error - Case 2

$$\begin{cases} Var = f(R_r) \\ e \propto NotCorr. \end{cases}$$





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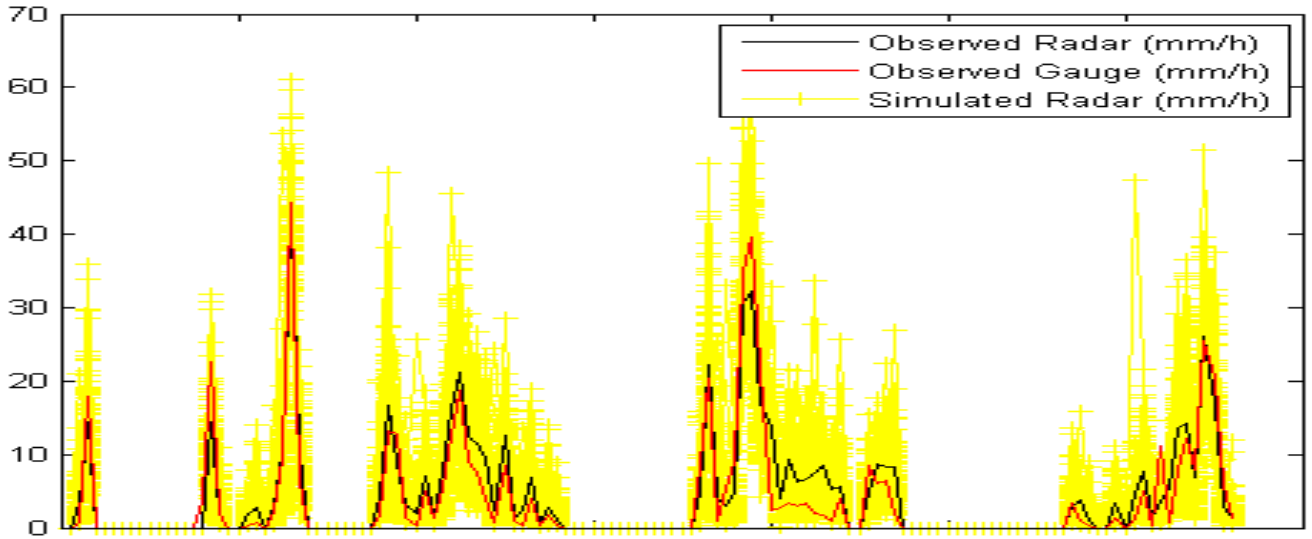
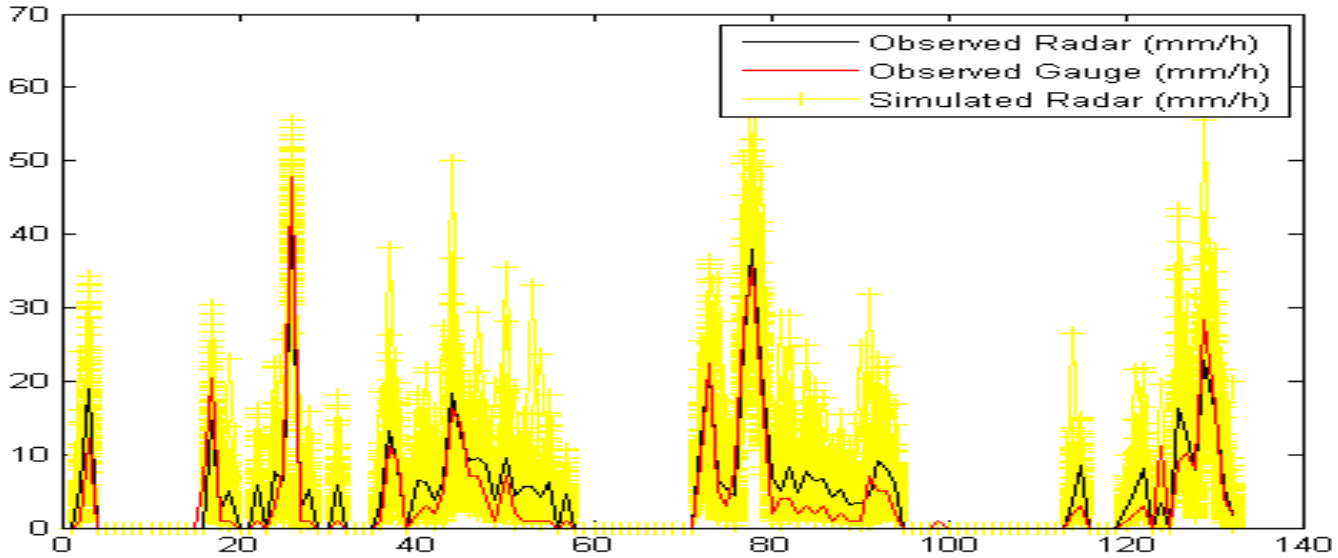
Simulation of Radar Error - Case 2

$$\begin{cases} Var = f(R_r) \\ e \propto NotCorr. \end{cases}$$

Pixel 2



Pixel 3



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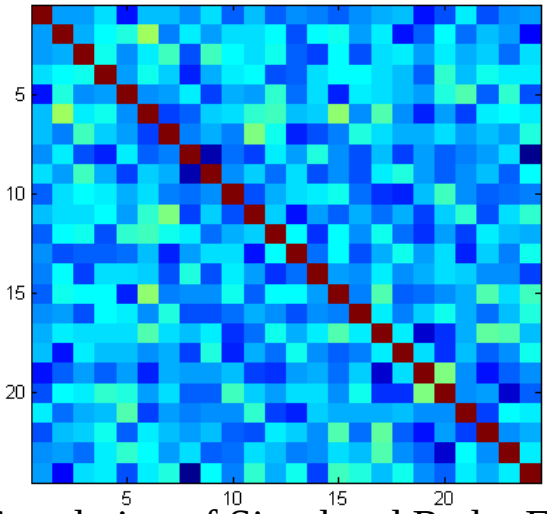
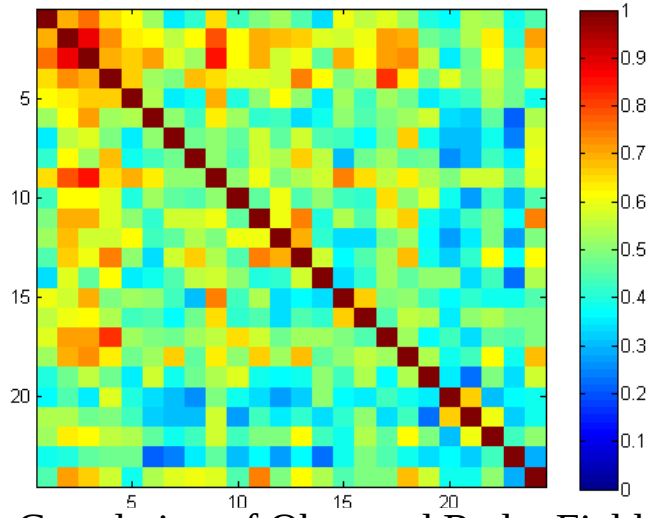
Simulation of Radar Error - Case 2

$$\begin{cases} Var = f(R_r) \\ e \propto NotCorr. \end{cases}$$

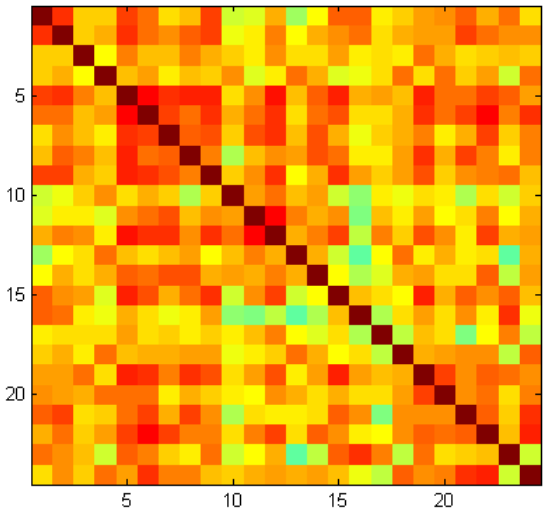
Correlation of Simulated Error Field



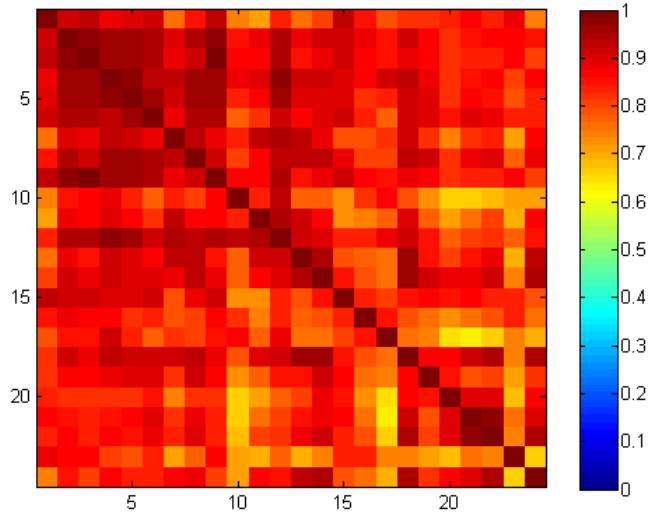
Correlation of Observed Error Field



Correlation of Simulated Radar Field



Correlation of Observed Radar Field



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Simulation of Radar Error - Case 3

$$\begin{cases} Var = f(R_r) \\ e \propto Corr. \end{cases}$$

The variance-covariance matrix can be decomposed using the Cholesky decomposition and used with Monte Carlo method to simulate random fields with similar variance-covariance matrices.

$$C = LL^*$$

Where L and L^* are lower triangular matrix and its transpose respectively.

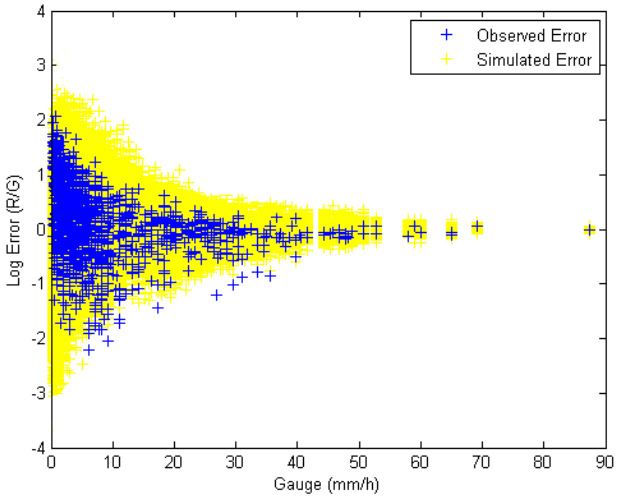
$$\varepsilon_i = \mu_i + L^* \Omega_i$$

$\varepsilon_i =$ Simulated vector of error

$\mu_i =$ Mean error vector

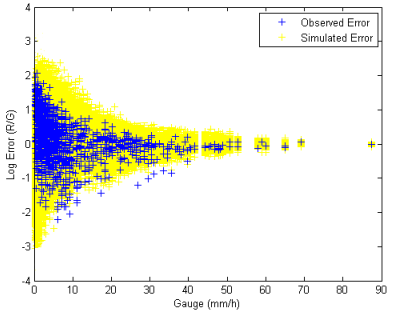
$L^* =$ Decomposed var-covar matrix

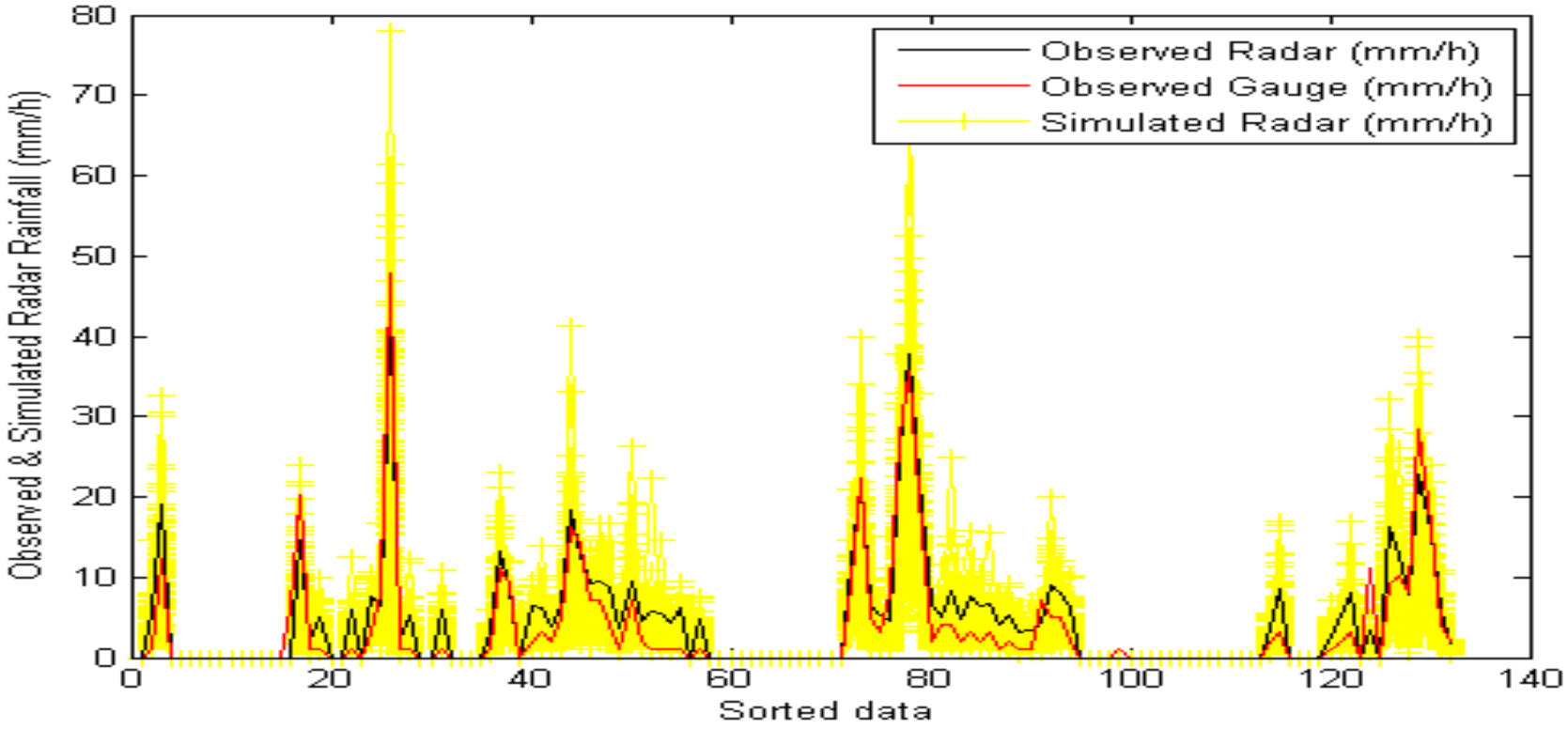
$\Omega_i =$ Random number generator



Simulation of Radar Error - Case 3

$$\begin{cases} Var = f(R_r) \\ e \propto Corr. \end{cases}$$





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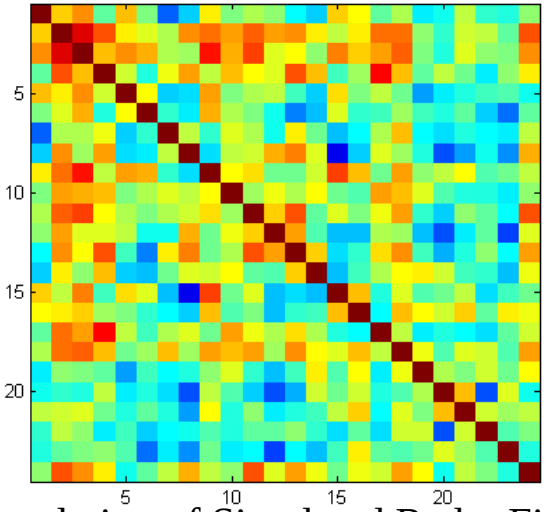
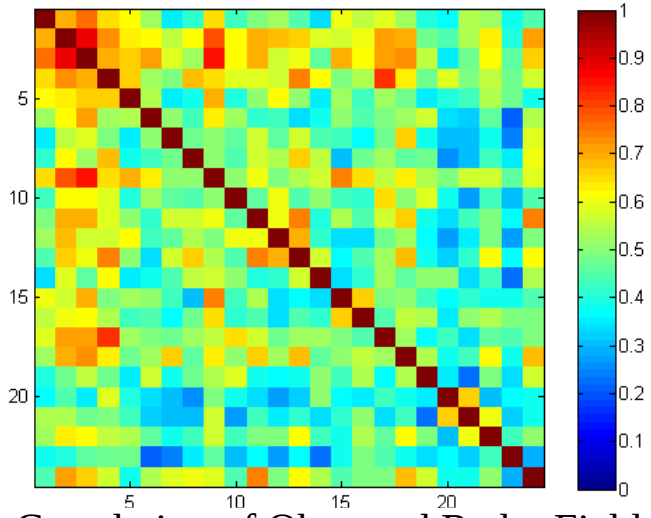
Simulation of Radar Error - Case 3

$$\begin{cases} Var = f(R_r) \\ e \propto Corr. \end{cases}$$

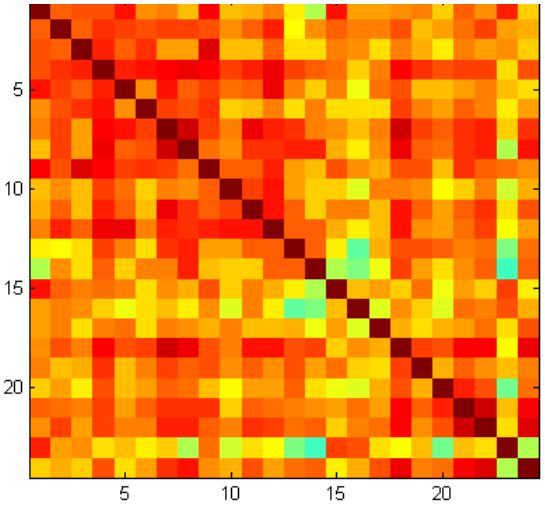
Correlation of Simulated Error Field



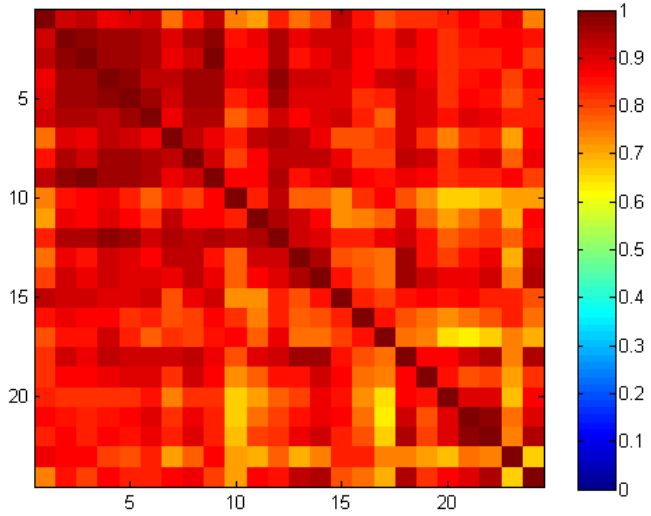
Correlation of Observed Error Field



Correlation of Simulated Radar Field



Correlation of Observed Radar Field



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Application in Hydrologic Modeling

The Physically based fully distributed GHSSA (Gridded Surface Subsurface Hydrologic Analysis) hydrological model is used to obtain resulting hydrographs of simulated radar fields (Ogden and Downer, 2002).

Model setup in this study:

- 2-D diffusive wave for overland flow and 1-D explicit diffusive wave method for channel flow
- Penman-Monteith equation for evapotranspiration
- Green&Ampt infiltration with redistribution method for flow simulation in the unsaturated zone

Calibration and Validation

Calibration:

April 10 - May 2, 1982

February 14 – March 2, 1987

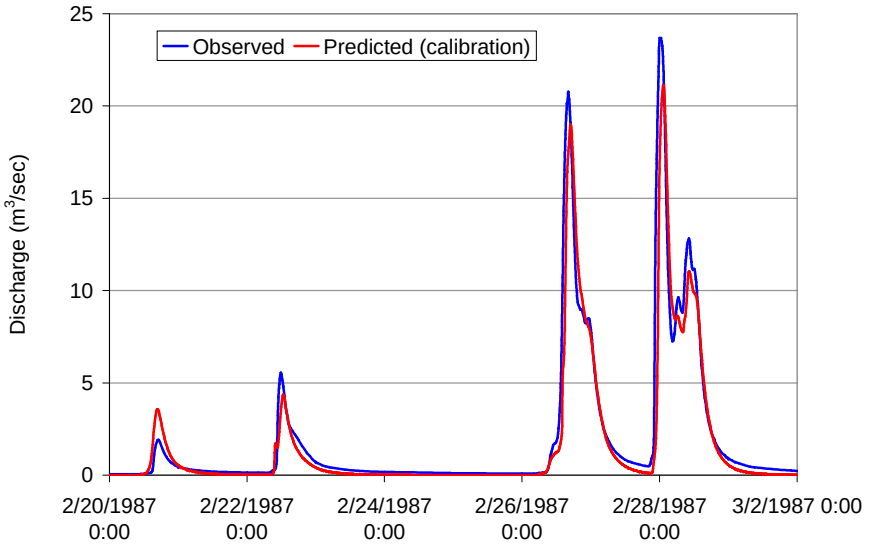
Validation:

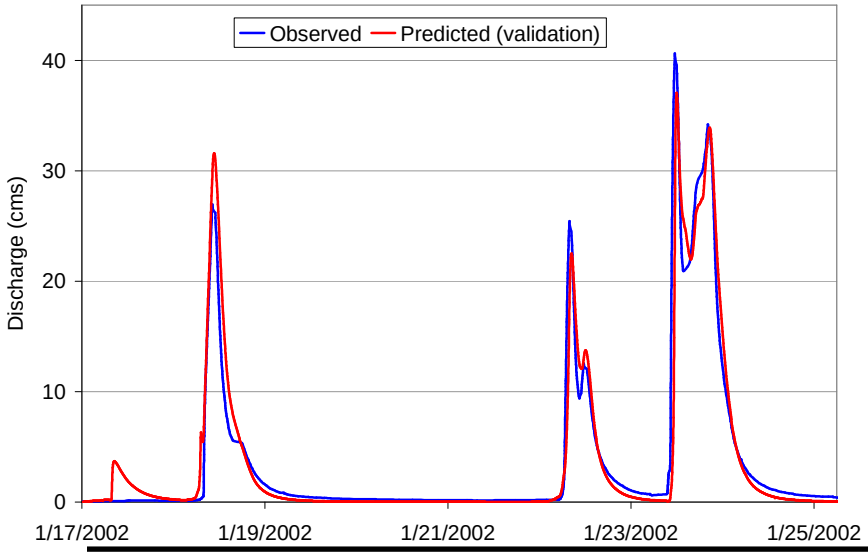
January 18, – March 8, 1997

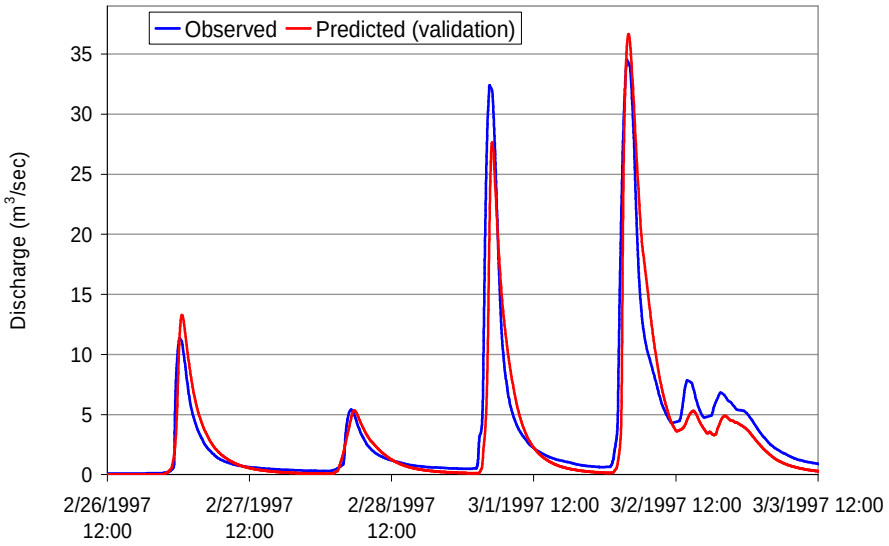
February 14 – March 1, 1998

January 11 – February 24, 2002

March 13 – May 7, 2002







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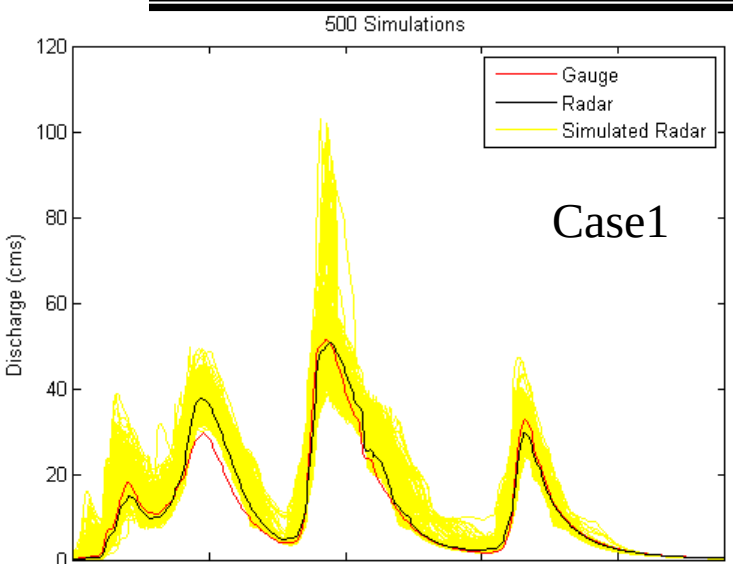
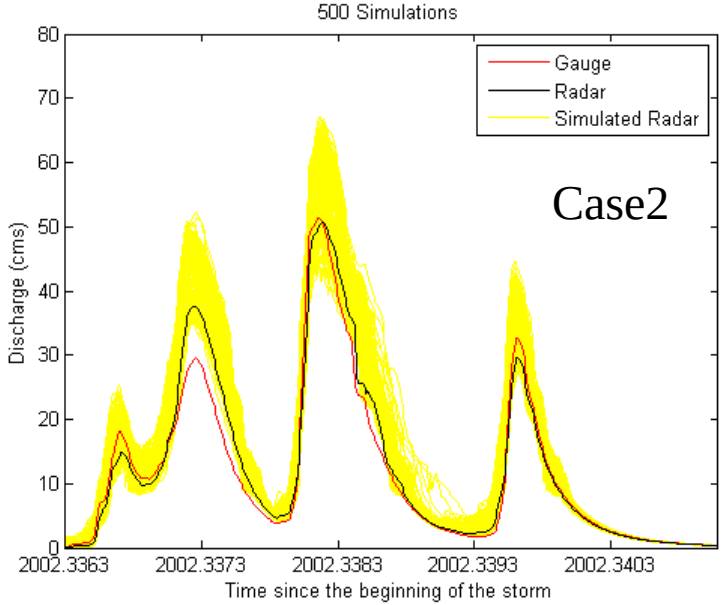
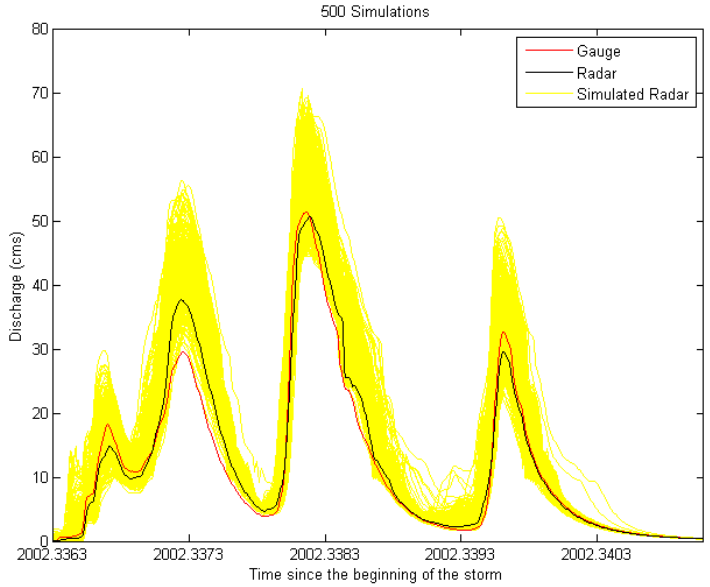
Application in Hydrologic Modeling





Case3



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Summary and Conclusions

Variance of radar error seems to reduce with the magnitude of radar.

Spatial dependencies of radar error fields are NOT negligible

Temporal dependencies of radar error fields seem to be negligible

Error fields were reasonably simulated using Monte Carlo simulation with Cholesky decomposition

The results of Case 3 where the variance was conditioned on the magnitude of radar and the spatial correlation was preserved, seemed to be more realistic.

THANK YOU FOR YOUR ATTENTION

AGU Joint Assembly, Fort Lauderdale, USA 27-30 May 2008