Hydrological-Driven Validation of MPE Precipitation Estimates

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Joint Assembly, Fort Lauderdale, Florida
May 2008

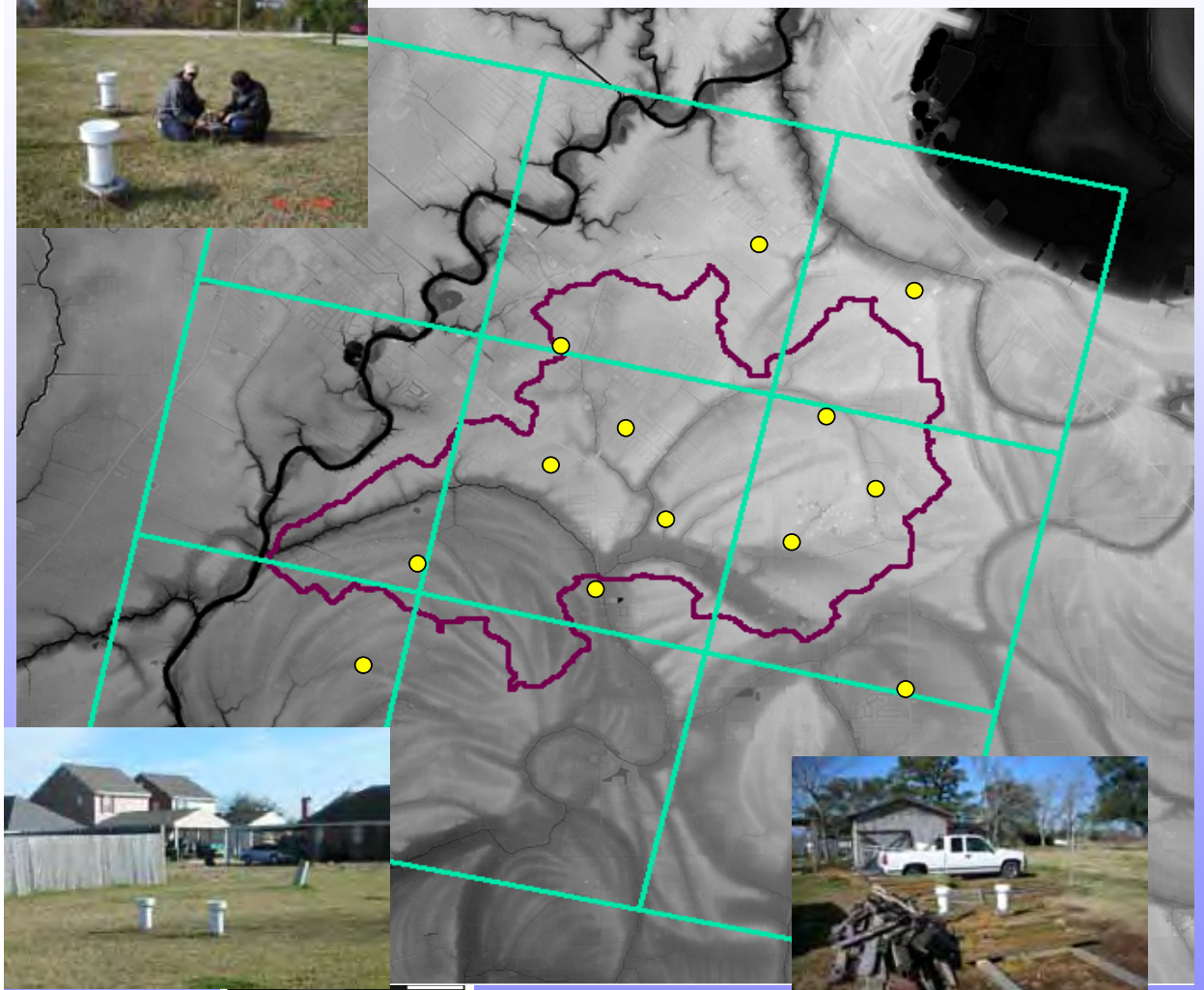
Objectives

- To provide an independent evaluation of MPE (NWS-RFC) at hydrological relevant scales
- To assess implications of sub-pixel variability for MPE evaluation
- To gain insight on practical value of MPE products for hydrological applications

Data Sources

- MPE products:
  - NWS LMRFC products
    - Stage III (MPE 2002) ----> Stage IV (NCEP)
- Rain gauge network
  - Independent
  - High quality of data
  - High density within scale of MPE product

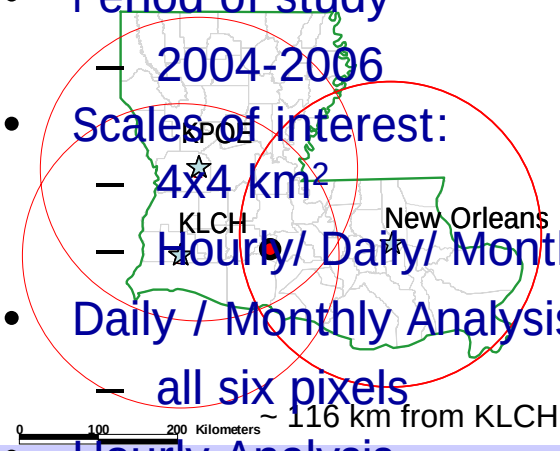
Rain Gauge Network in Lafayette, LA

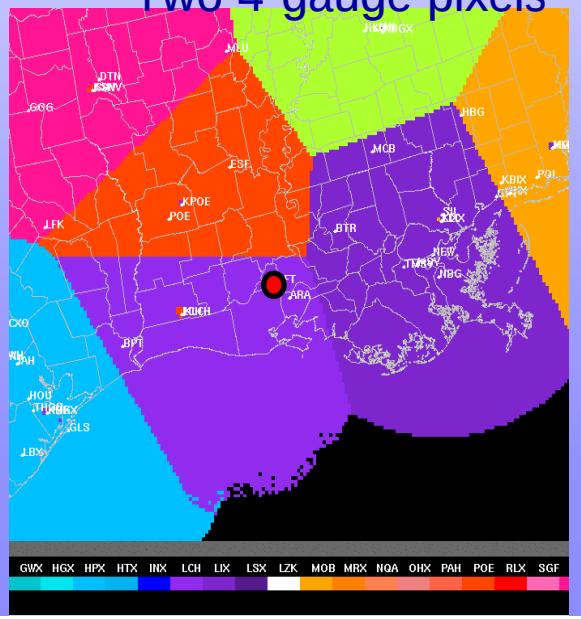


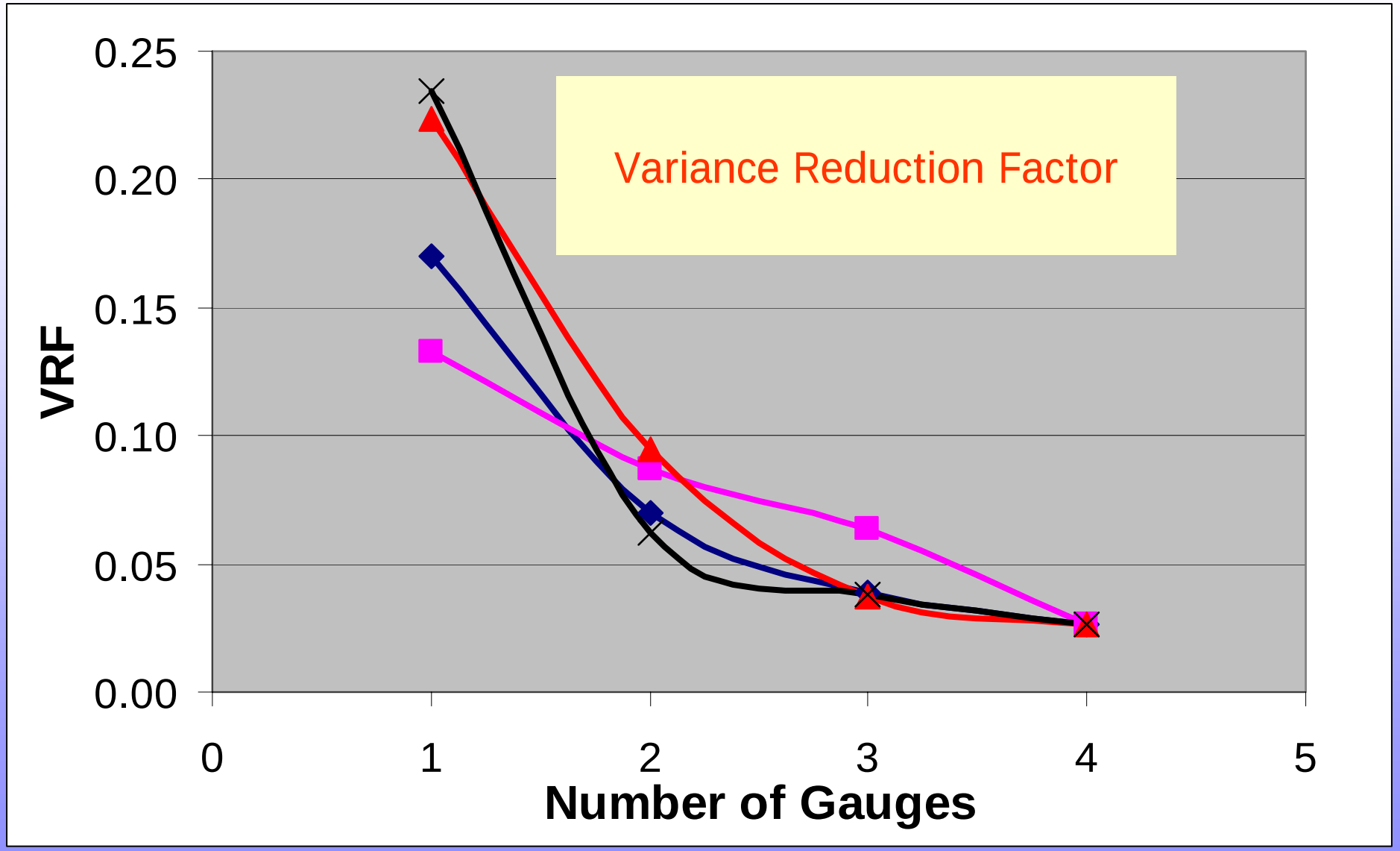
4 Km

Annual precipitation = 55-60 inches

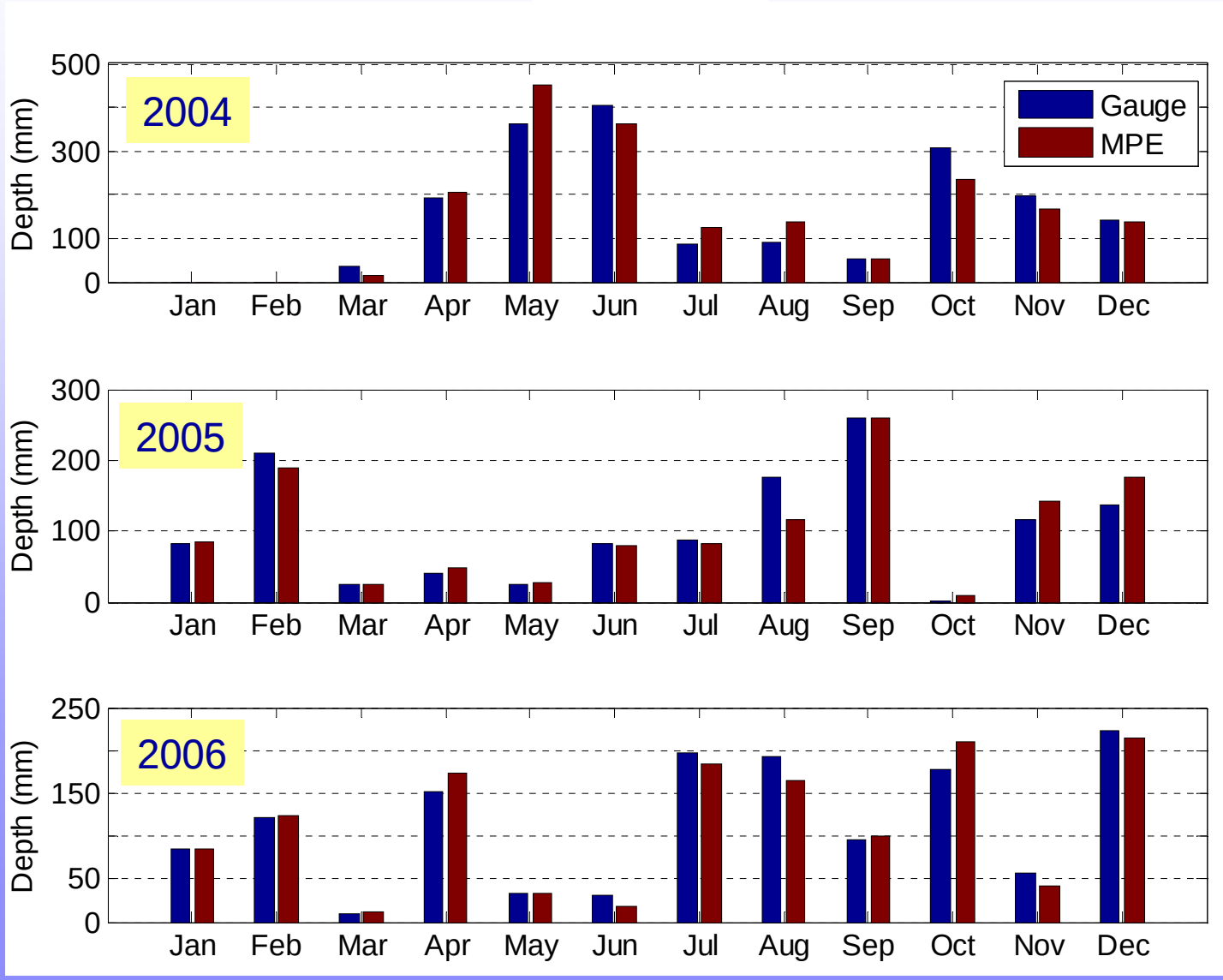
- Period of study
  - 2004-2006
- Scales of interest:
  - 4x4 km^2
  - Hourly/ Daily/ Monthly
- Daily / Monthly Analysis
  - all six pixels
- Hourly Analysis
  - Two 4-gauge pixels



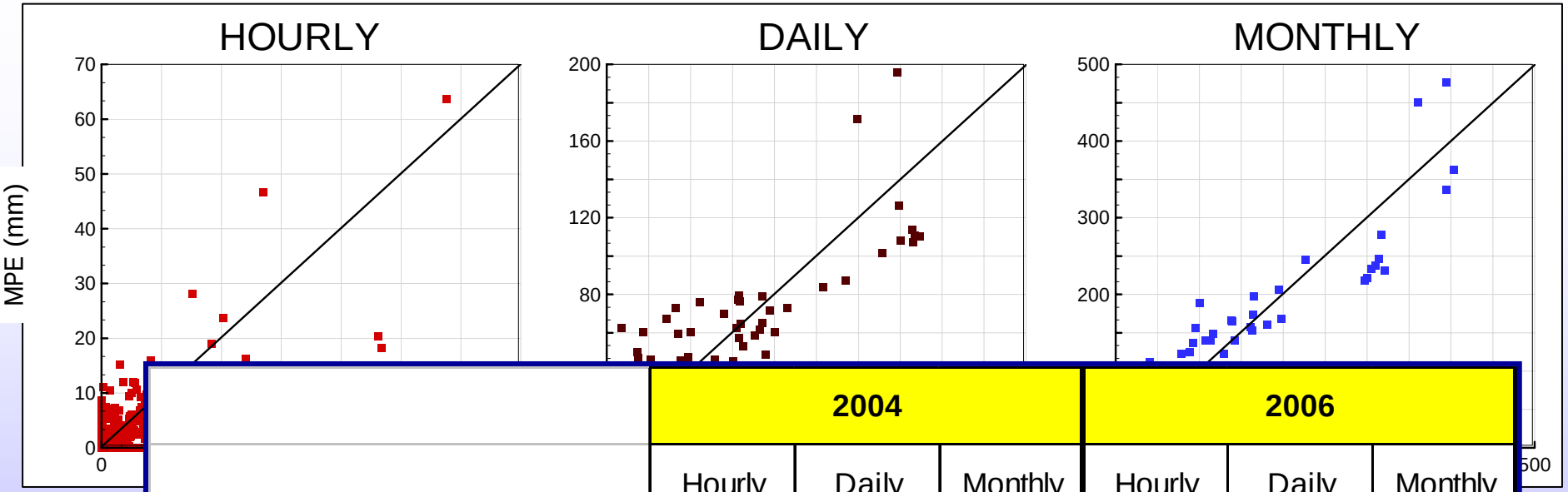



Variance Reduction Factor
VRF
0.25
0.20
0.15
0.10
0.05
0.00
0
1
2
3
4
5
Number of Gauges

Monthly Comparisons

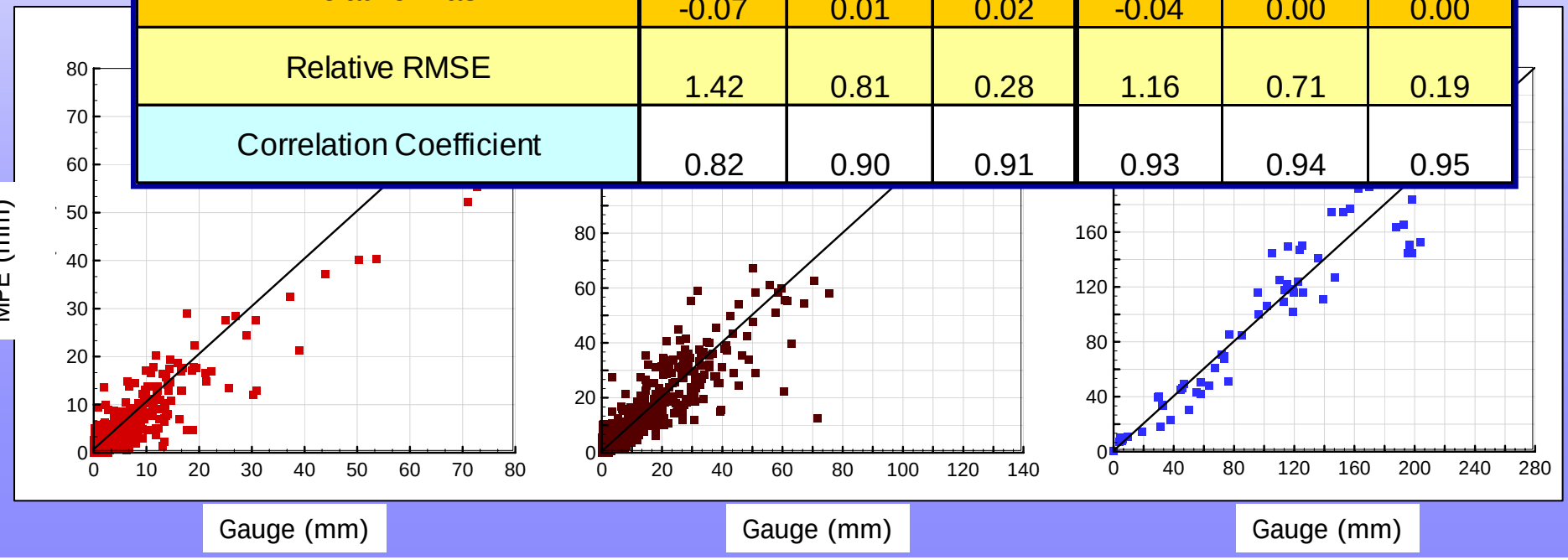


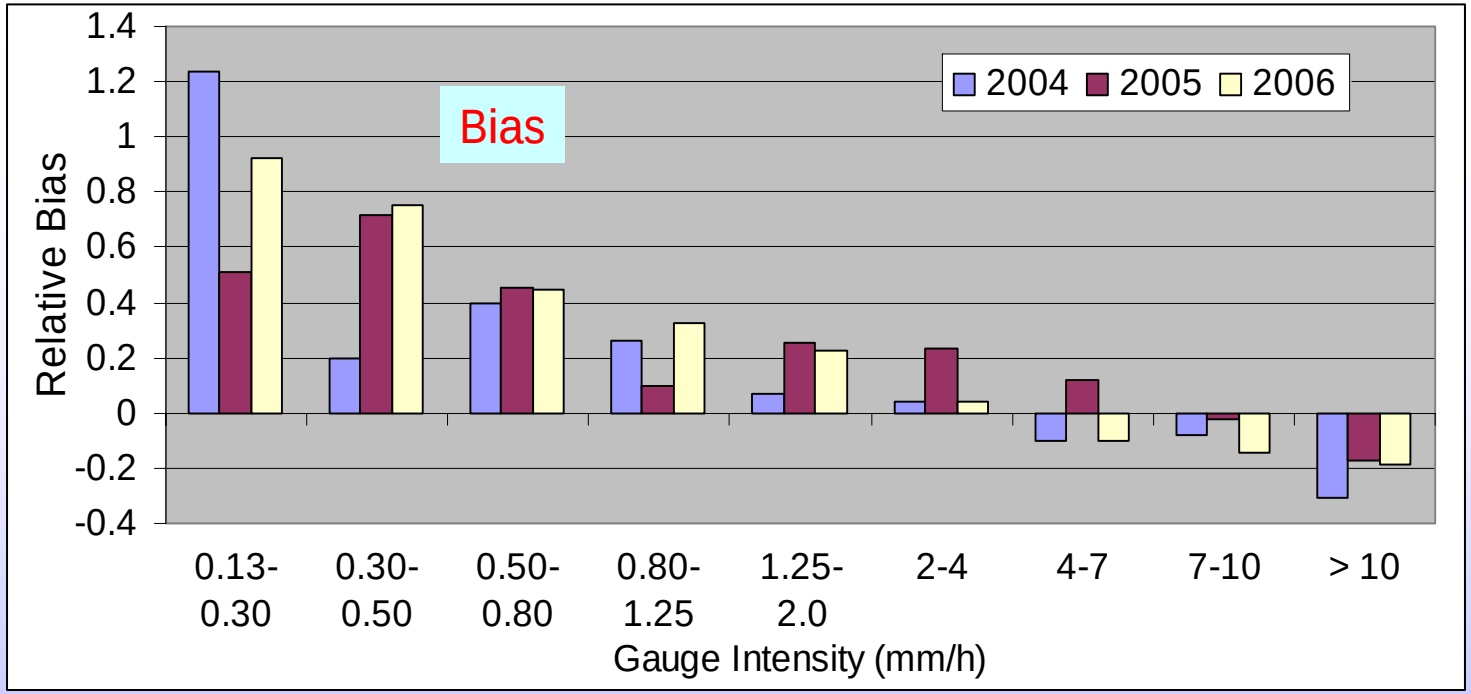
2004

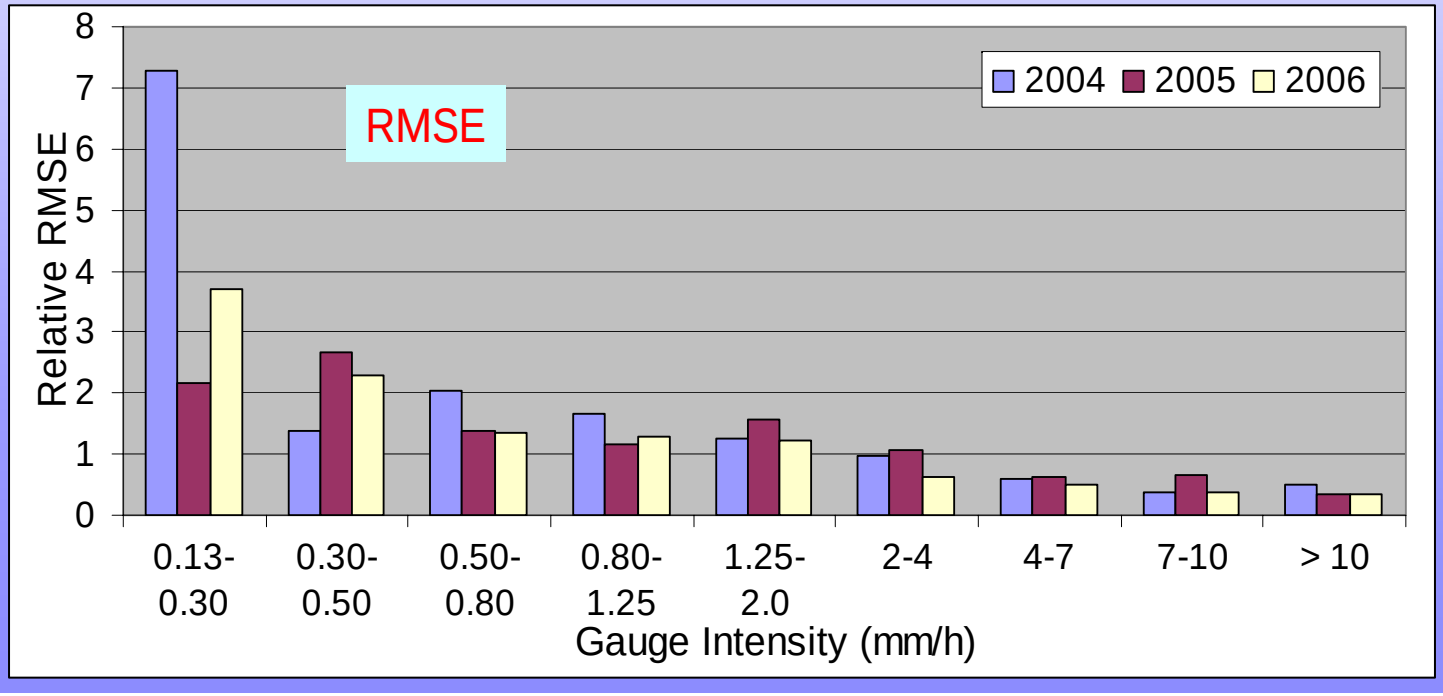


	2004			2006		
	Hourly	Daily	Monthly	Hourly	Daily	Monthly
Relative Bias	-0.07	0.01	0.02	-0.04	0.00	0.00
Relative RMSE	1.42	0.81	0.28	1.16	0.71	0.19
Correlation Coefficient	0.82	0.90	0.91	0.93	0.94	0.95

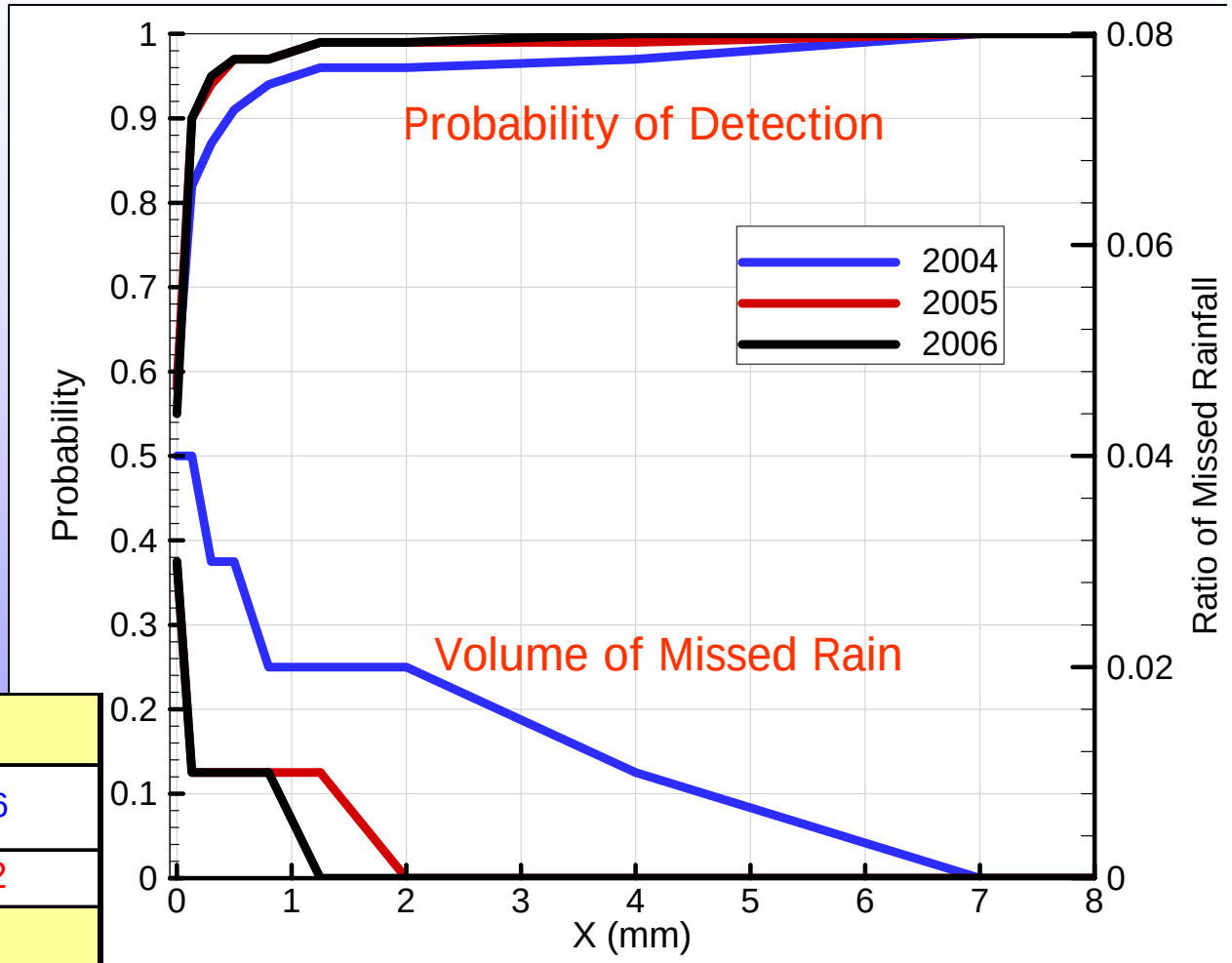
2006




Bias
2004
2005
2006
Relative Bias
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0.13-0.30
0.30-0.50
0.50-0.80
0.80-1.25
1.25-2.0
2-4
4-7
7-10
> 10
Gauge Intensity (mm/h)


RMSE
2004
2005
2006
Relative RMSE
8
7
6
5
4
3
2
1
0
0.13-0.30
0.30-0.50
0.50-0.80
0.80-1.25
1.25-2.0
2-4
4-7
7-10
> 10
Gauge Intensity (mm/h)

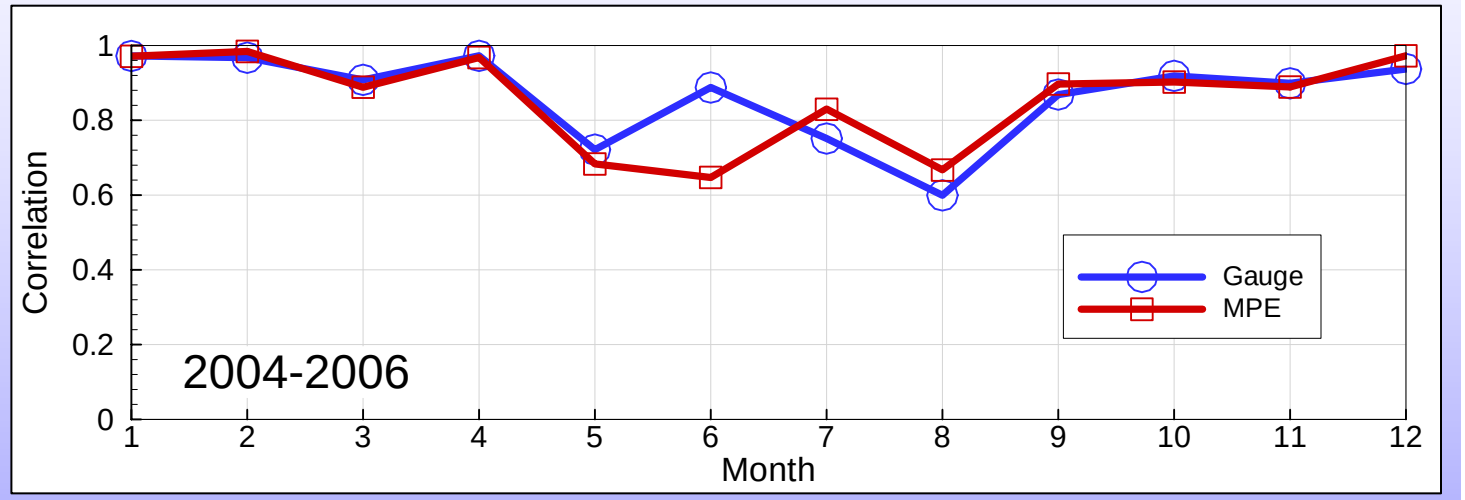
Categorical metrics



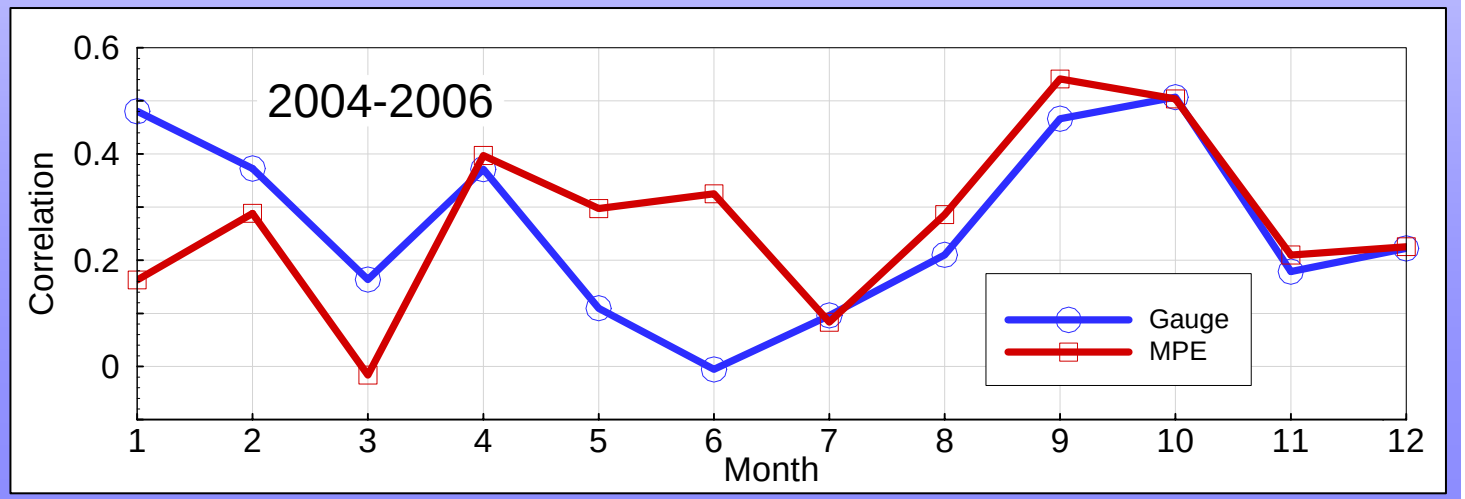
False Alarm Ratio (FAR)		
2004	2005	2006
0.01	0.01	0.02
Total Rainfall Falsely Detected		
2004	2005	2006
6% (7.86 cm)	3% (7.93 cm)	4% (11.98 cm)

Spatio-Temporal Structure

Spatial Correlation: 4-km lag

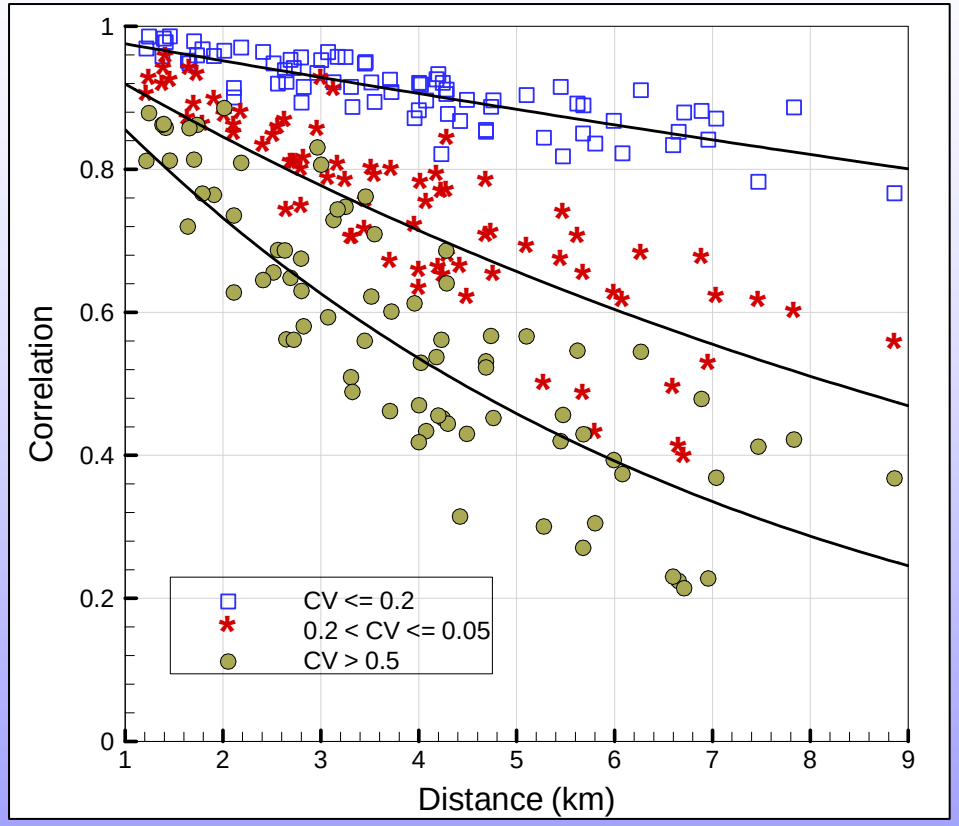


Temporal Correlation: 1-hour lag

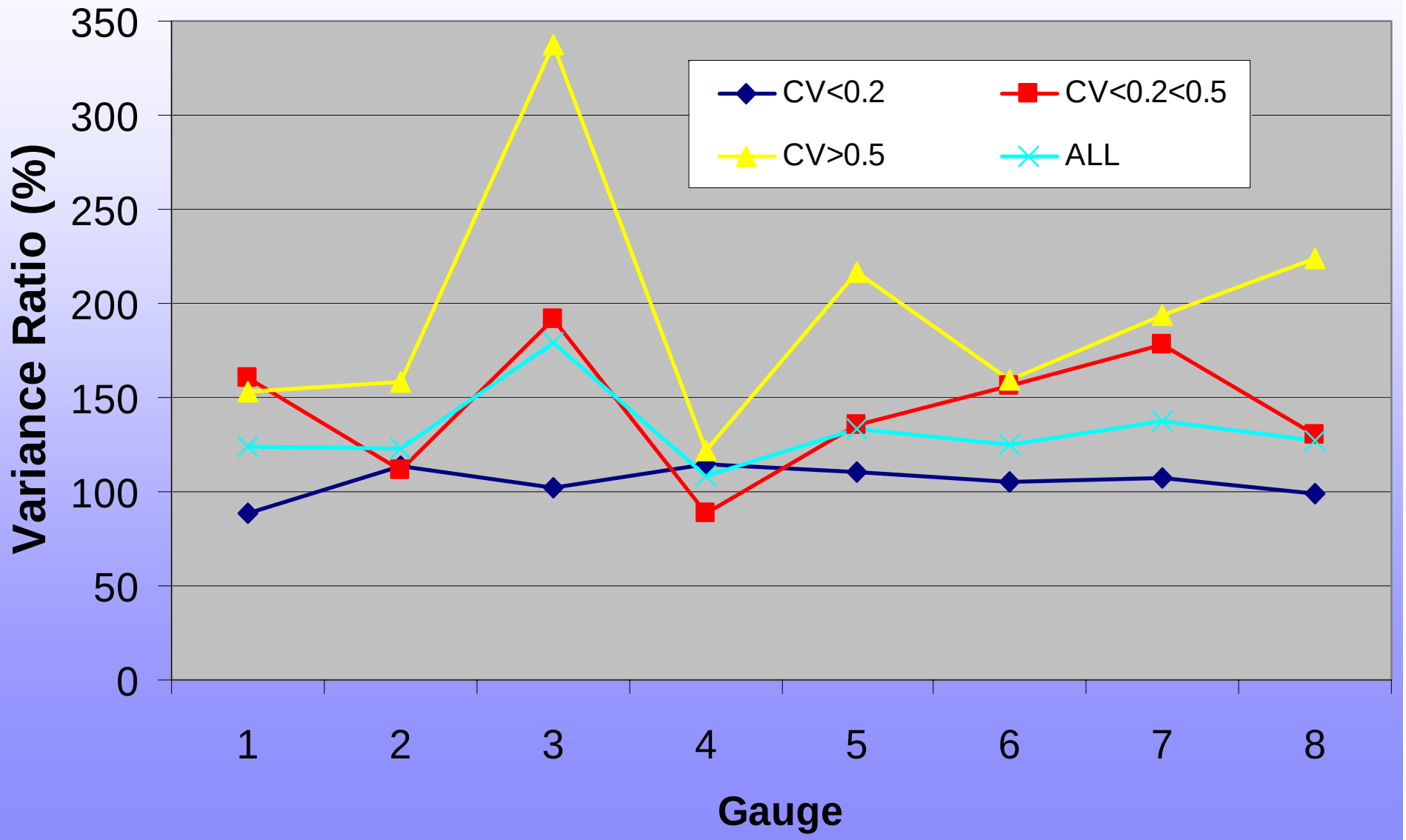


Effect of sub-pixel variability

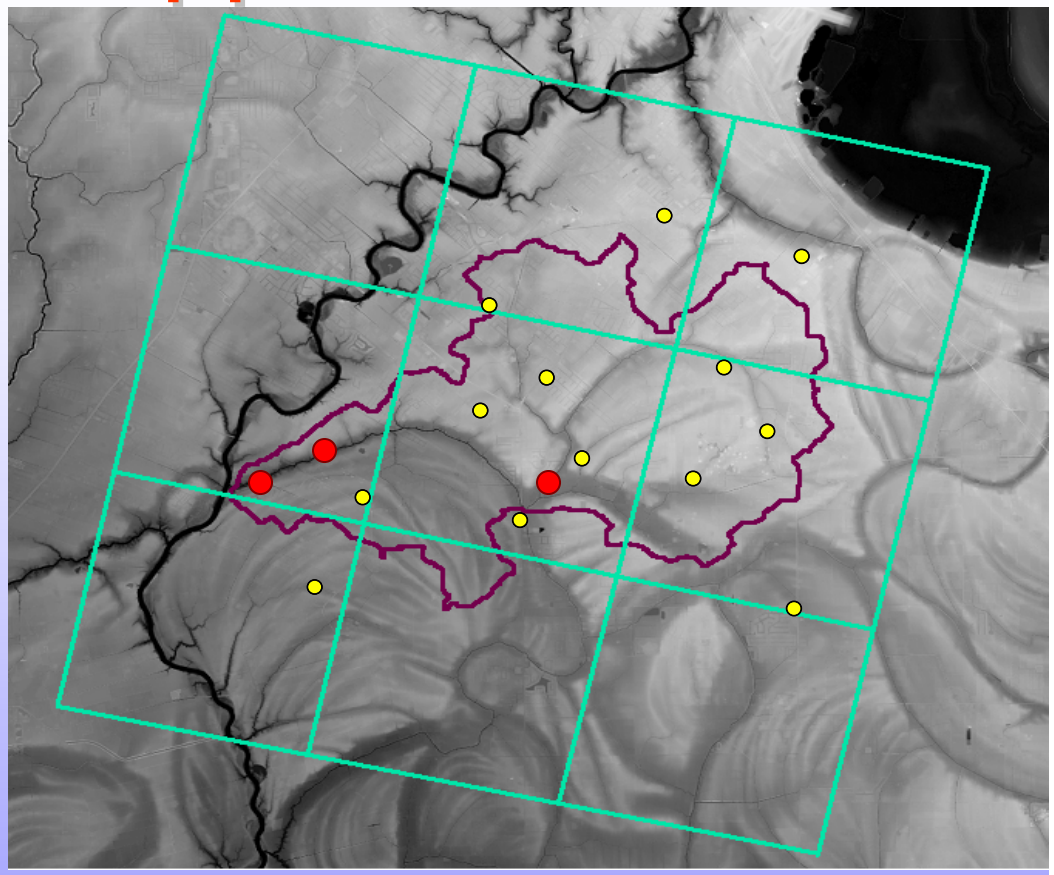
$$\mathrm{Var}(\mathrm{MPE}\text{-}G_i) = \mathrm{Var}(\mathrm{MPE}\text{-}\mathrm{True}) + \mathrm{Var}(G_i\text{-}\mathrm{True}) - 2\mathrm{Cov}[(\mathrm{MPE}\text{-}\mathrm{True}), (G_i\text{-}\mathrm{True})]$$



Var(MPE-G) / Var(MPE-True)

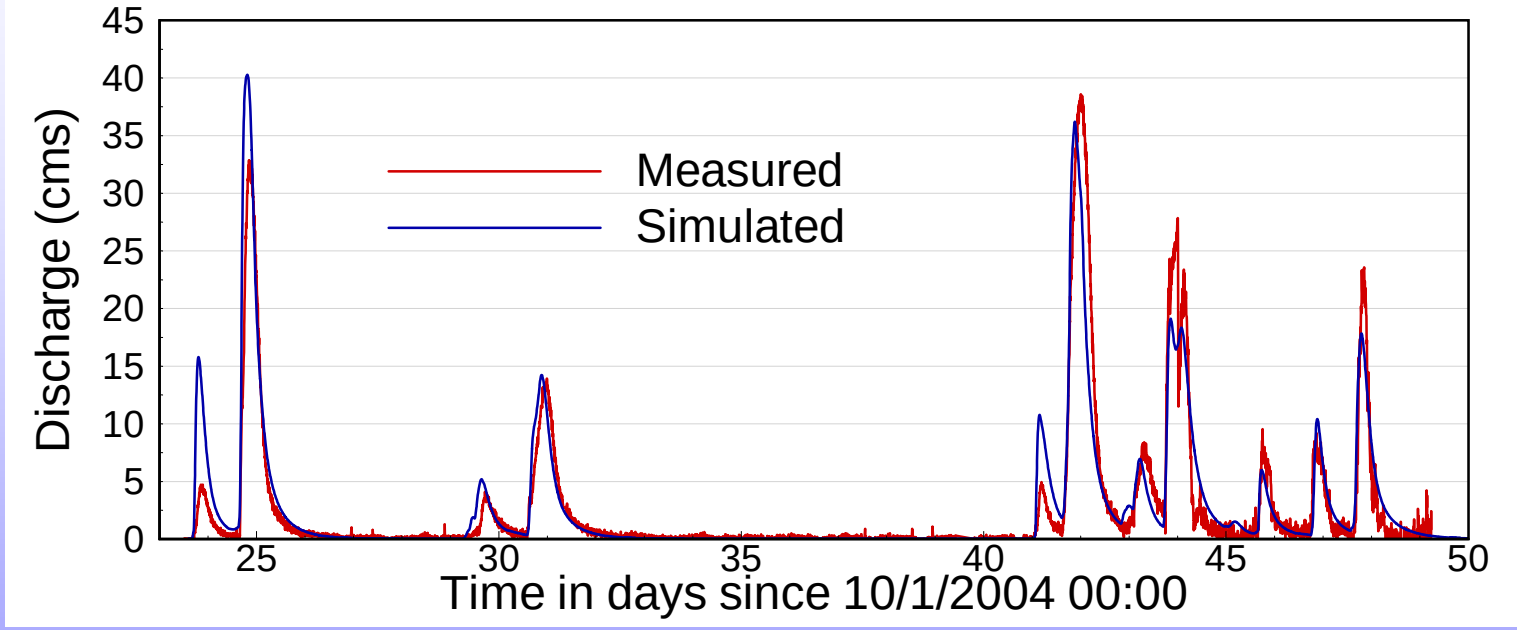


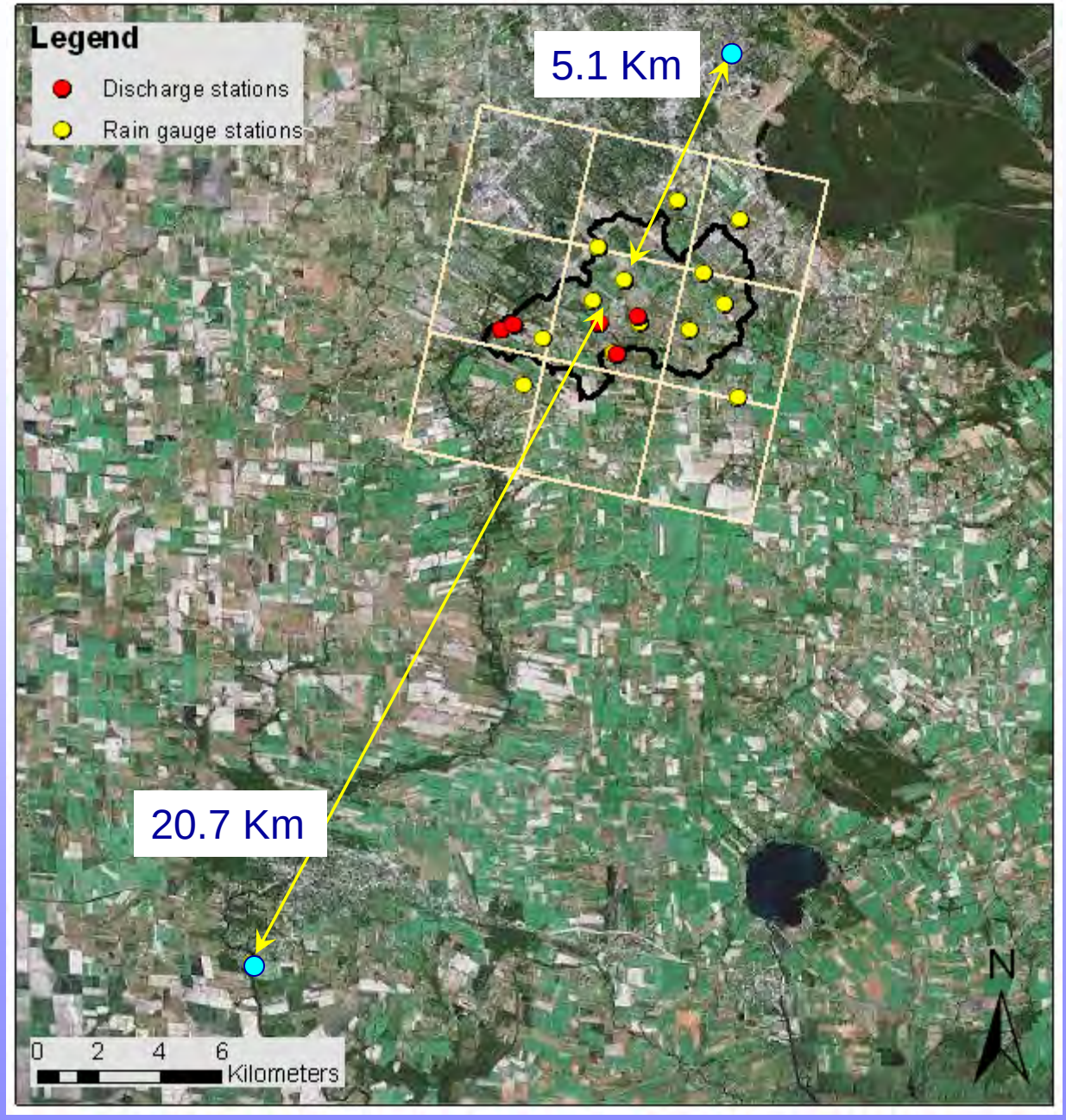
Hydrologic Application:



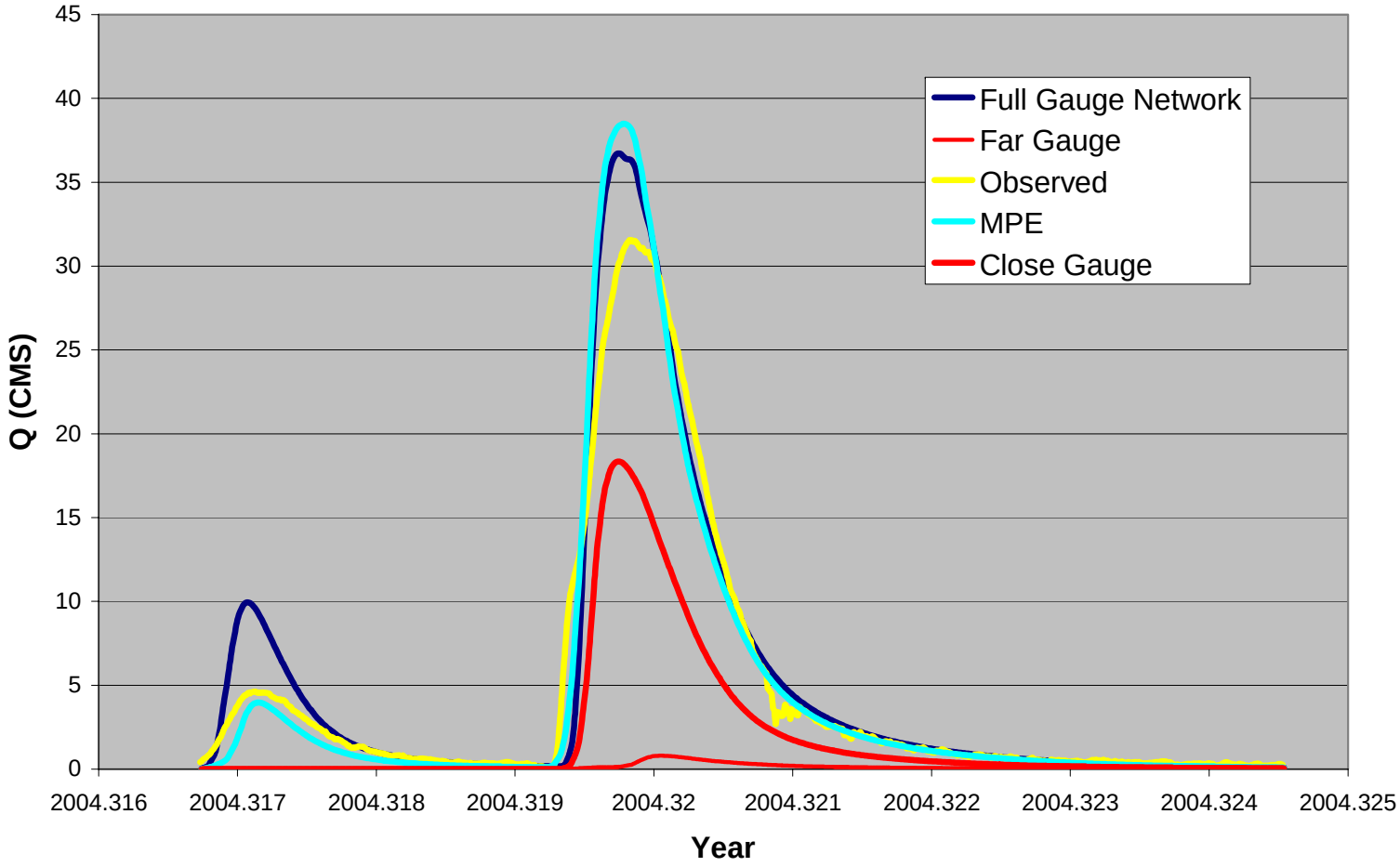
- GSSHA: Physically-based fully distributed hydrologic modeling system (Ogden and Downer, 2002)
- Model Setup:
  - 2-d diffusive wave for overland flow
  - 1-d explicit diffusive wave for channel flow
  - Penman-Monteith equation for ET
  - Green and Ampt infiltration with redistribution

Calibration/Validation

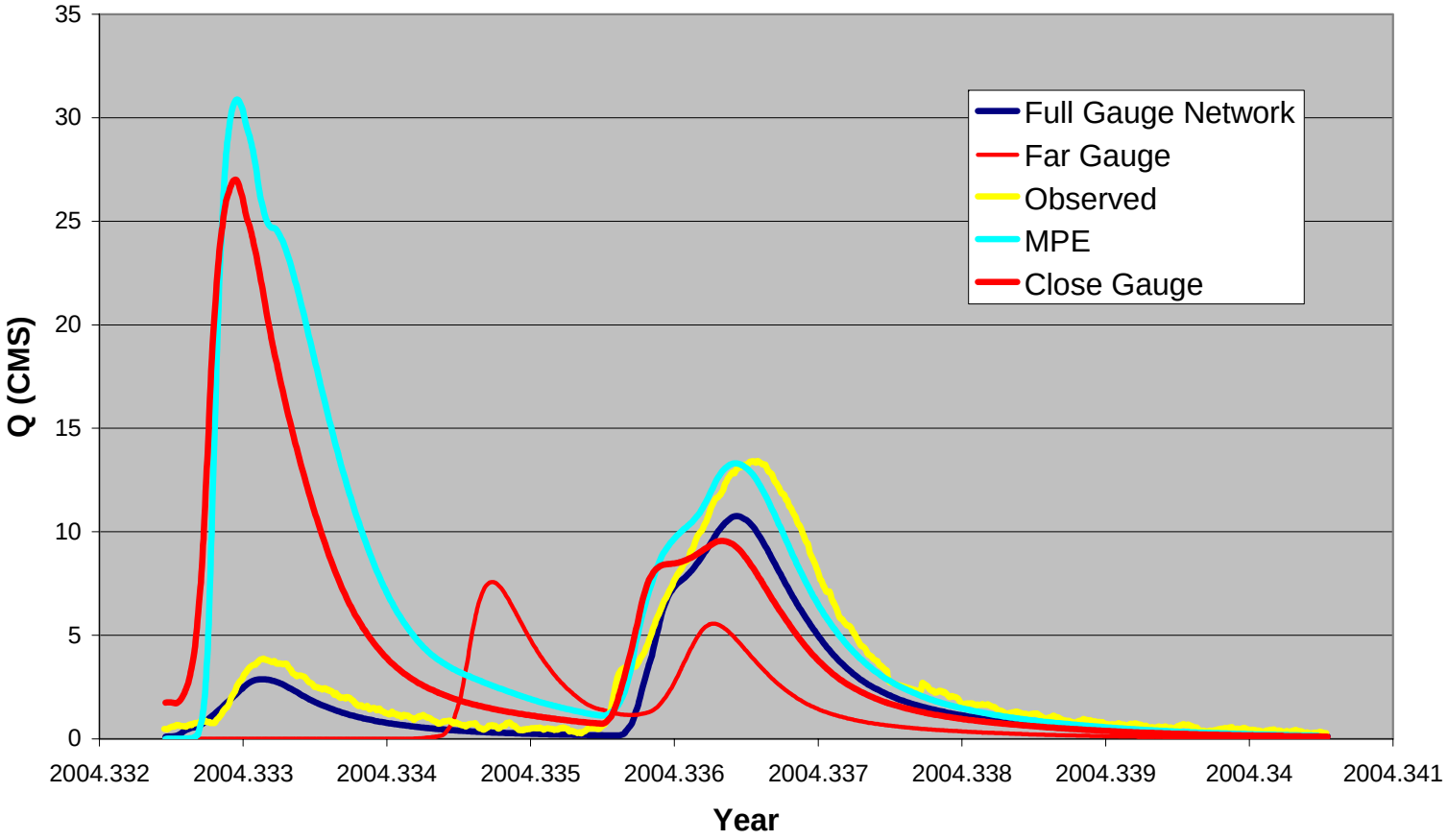



Legend
Discharge stations
Rain gauge stations
5.1 Km
20.7 Km
0 2 4 6
Kilometers
N

Period 1


45
40
35
30
25
20
15
10
5
0
Q (CMS)
2004.316
2004.317
2004.318
2004.319
2004.32
2004.321
2004.322
2004.323
2004.324
2004.325
Year
Full Gauge Network
Far Gauge
Observed
MPE
Close Gauge

Period 2


35
30
25
20
15
10
5
0
Q (CMS)
2004.332
2004.333
2004.334
2004.335
2004.336
2004.337
2004.338
2004.339
2004.34
2004.341
Year
Full Gauge Network
Far Gauge
Observed
MPE
Close Gauge

Conclusions & Future Work

- Overall bias is minimal (2-7% at hourly scale; almost zero at daily/monthly scales)
- MPE has conditional bias: overestimation at low rainfall and underestimation at high rainfall
- MPE has conditional variance: variance decreases with increase of intensity
- high probability of detection (> 90%) except at very small intensities
- Low probability of false detection (1-2%) – results in 3-5% falsely detected rain

Conclusions & Future Work

- Relying on a single gauge for validation can cause overestimation of MPE errors by ~150%-200%
- For runoff purposes, MPE have noticeable value over typical rain gauge availability situations.
- Future work: use the same network and other similar research networks to look at other QPE products

Acknowledgements

- Funding provided by:
  - UCAR under sponsorship of NOAA/DOC as part of the COMET Outreach Program.
  - Louisiana Board of Regents, BoRSF, agreement NASA/LEQSF (2005-2010)-LaSPACE and NASA/LaSPACE, grant NNG05GH22H
  - University of Louisiana at Lafayette

Thank You!

Continuous Statistics

Normalized Bias

$$B = \frac{\left(\sum_{i=1}^{n} \left(R_{i\,MPE} - R_{i\,RG} \right) \right)}{\overline{R_{RG}}}$$

Normalized Root Mean Square Error

$$RMSE = \frac{\sqrt{\frac{1}{n} \sum_{i=1}^{n} \left(\left(R_{i\,MPE} - R_{i\,RG} \right)^2 - \left(\overline{R_{RG}} - \overline{R_{MPE}} \right)^2 \right)}}{\overline{R_{RG}}}$$

Pearson Correlation

$$\rho(R_{RG}, R_{MPE}) = \frac{\overline{R_{RG} R_{MPE}} - \left(\overline{R_{RG}} \right) \left(\overline{R_{MPE}} \right)}{\sqrt{\left(\overline{R_{RG}^{\,2}} - \overline{R_{RG}}^{\,2} \right) \left(\overline{R_{MPE}^{\,2}} - \overline{R_{MPE}}^{\,2} \right)}}$$

Efficiency

$$E = 1 - \frac{\left(\sum_{i=1}^{n} \left(R_{i\,MPE} - R_{i\,RG} \right)^2 \right)}{\left(\sqrt{\frac{1}{n} \sum_{i=1}^{n} \left(R_{i\,RG} - \overline{R_{RG}} \right)^2} \right)^2}$$

Conditional Validation based on Rainfall Magnitude and Season

- Rainfall Magnitude conditioning
  - Define a relationship between gauge and MPE as a function of rainfall intensity.
  - 9 intensity intervals used (0.13 mm/hr → >10 mm/hr)
- Seasonal conditioning
  - Define any seasonal relationship between gauge and MPE.
  - Hourly statistics plotted on a monthly basis.

Season-based Statistics

	Highly Uniform (Cold Months)		Less Uniform (Transitional Months)		Non-uniform (Warm Months)	
	Average Gauge	Single Gauge	Average Gauge	Single Gauge	Average Gauge	Single Gauge
Gauge Mean (mm)	2.21		1.90		2.93	
Normalized Bias	0.06	0.06	-0.04	-0.04	-0.20	-0.20
Normalized RMSE	1.01	1.13	1.21	1.34	1.07	1.33
Correlation Coefficient	0.92	0.90	0.85	0.81	0.87	0.81
Efficiency	0.84	0.80	0.72	0.65	0.74	0.63

Analyzing Sub-pixel Rainfall Variability

Single Gauge or Average Gauge

- Stratified based on CV
  - $CV \leq 0.2$
  - $0.2 < CV \leq 0.5$
  - $CV > 0.5$

- Stratified based on season
  - Cold months (Dec – Feb)
  - Transitional months (Mar – May, Sep - Nov)
  - Warm months (Jun – Aug)

Self-correlation Statistics

All self-correlation performed at hourly time scale.

- Spatial (G_1 vs. G_2 / MPE_1 vs. MPE_2)
  - Two 4-gauge pixels
  - Representative of 4 km.
- Temporal (G/MPE)
  - One 4-gauge pixel
  - 1 hr time shift

MPE Development at River Forecast Center (RFC)

-Precipitation Processing System (PPS)

- Reflectivity preprocessing (QC)
- Conversion of (Z) to (R). $Z=250R^{1.2}$, $Z=300R^{1.4}$

-STAGE I ~ Digital Precipitation Array (DPA)

- Hourly radar-only product over (HRAP) grid

-Mean Field Bias Correction

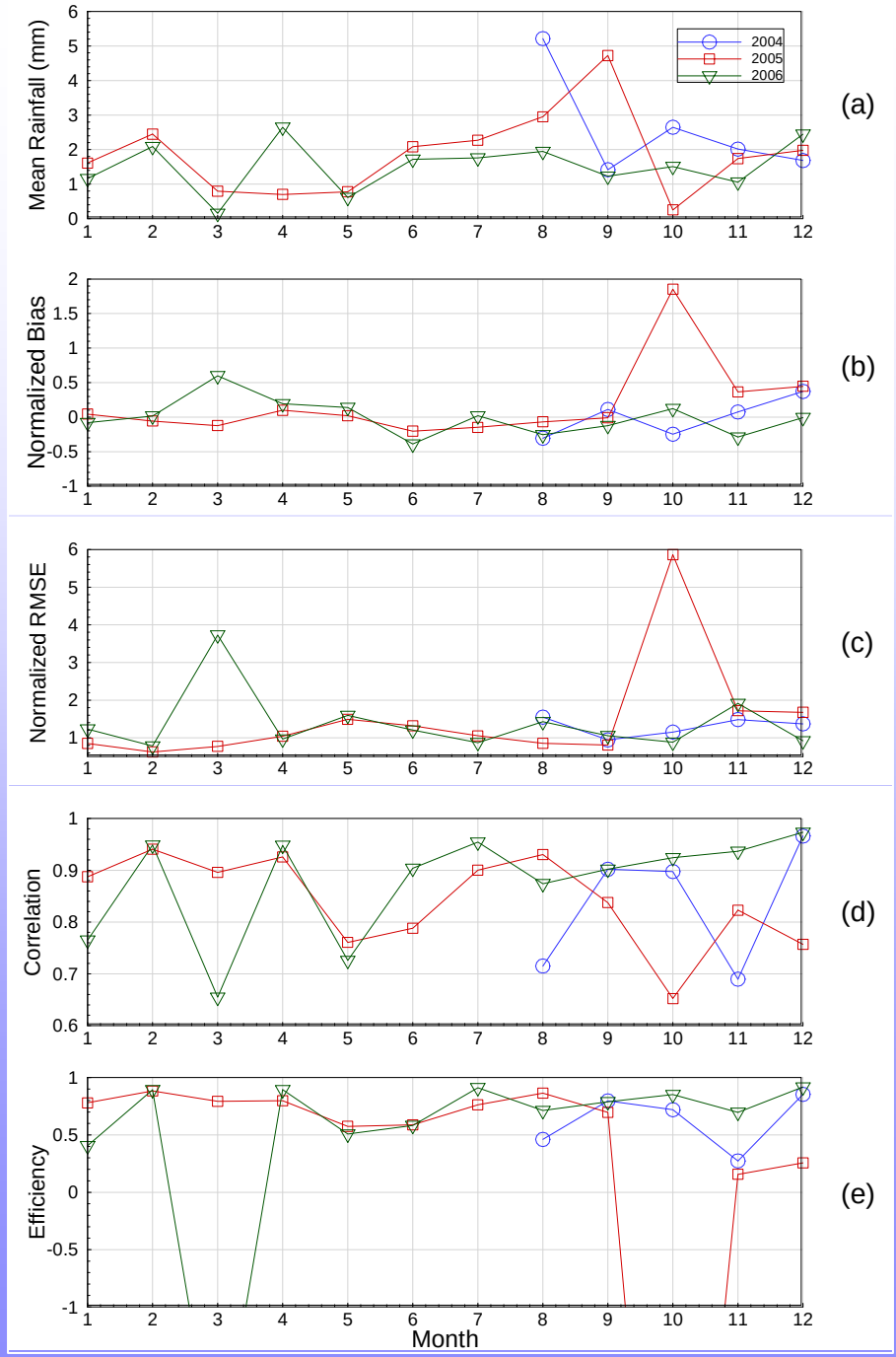
- Rain gauges to correct multiplicative bias

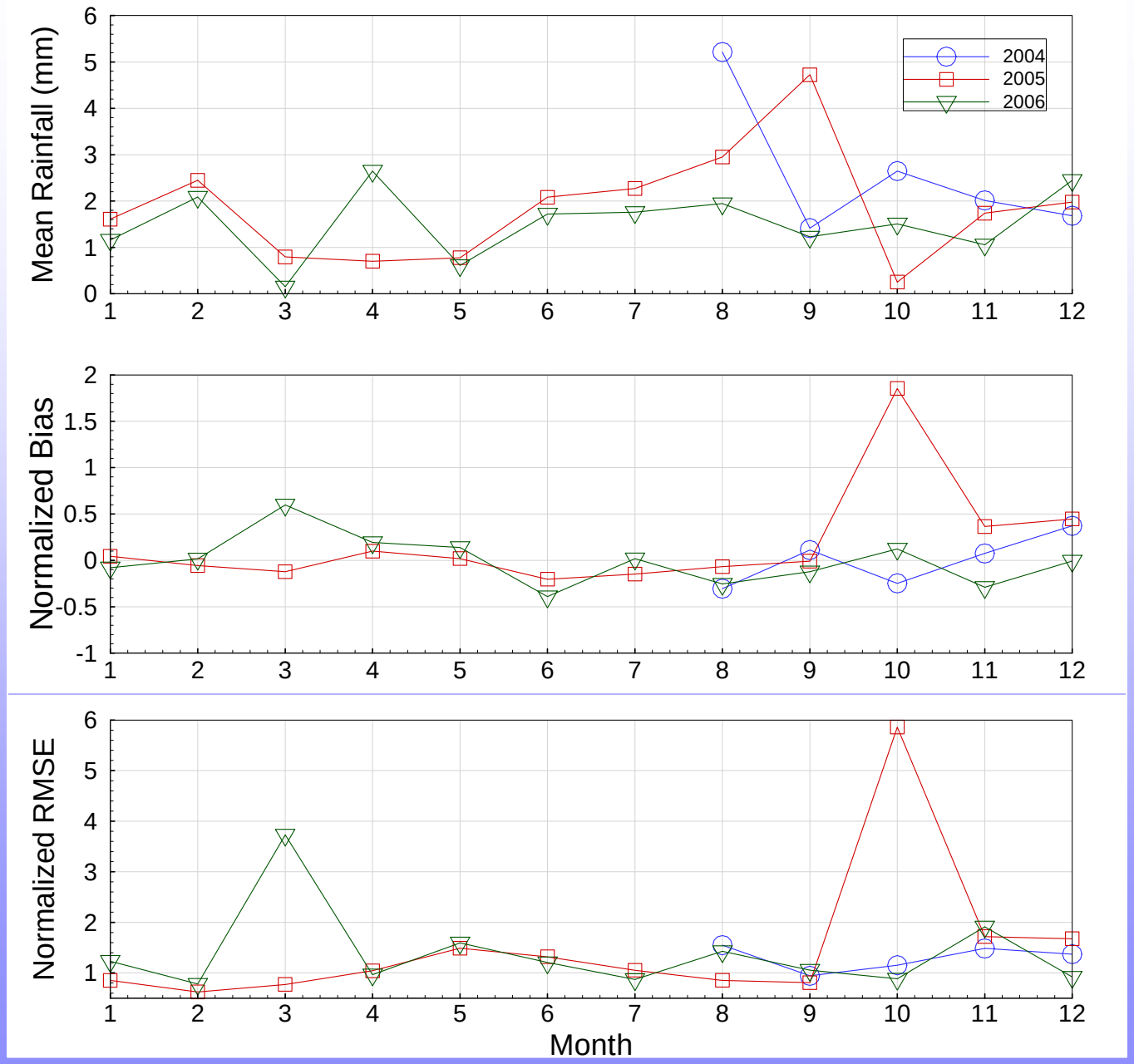
-STAGE II ~ mean field bias correcting of DPA

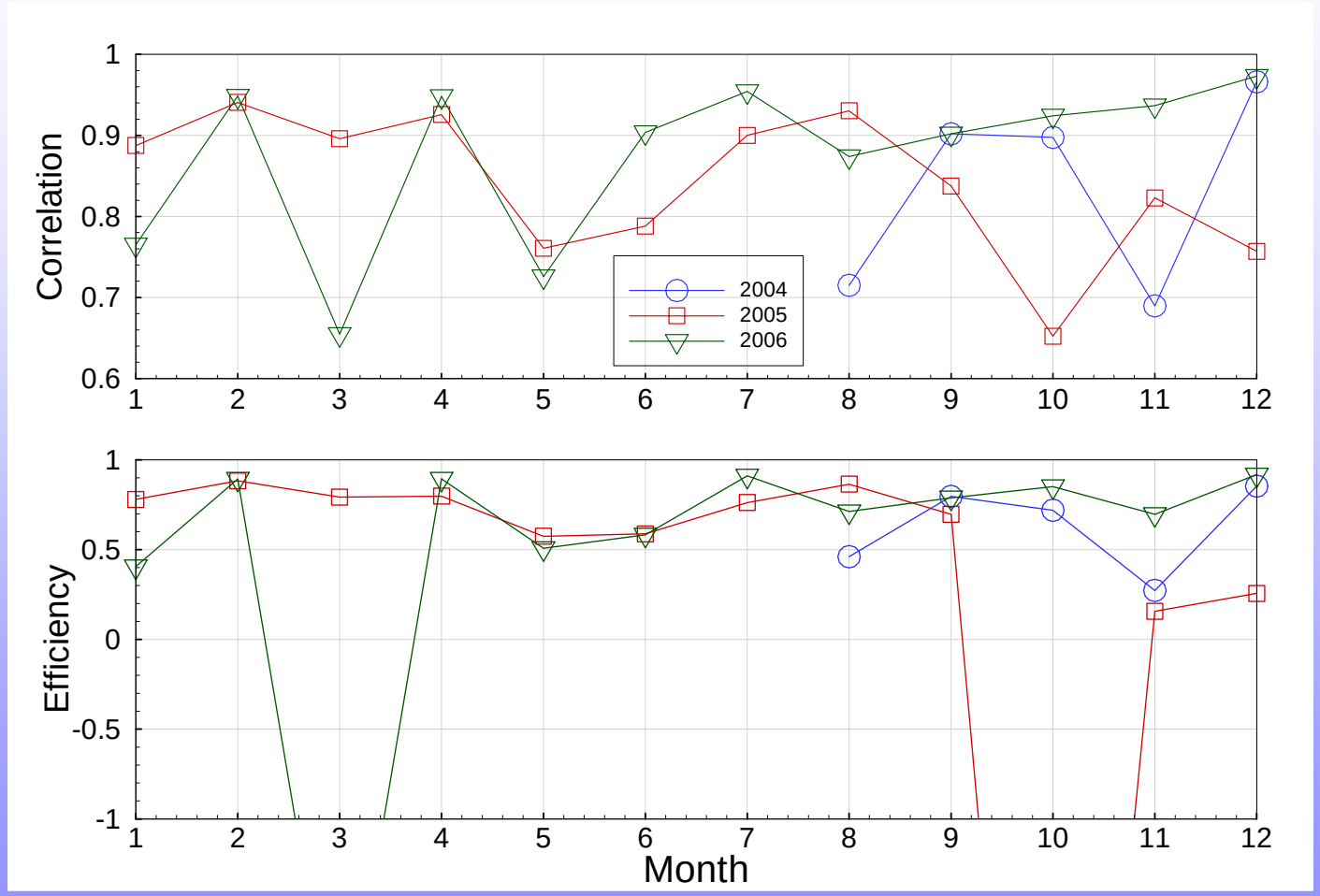
-STAGE III ~ mosaicking Stage II over each RFC domain. (Replaced in 2002 with MPE)

-STAGE IV ~ creation of quilted national product of radar-based estimates by The National Center for Environmental Prediction (NCEP)

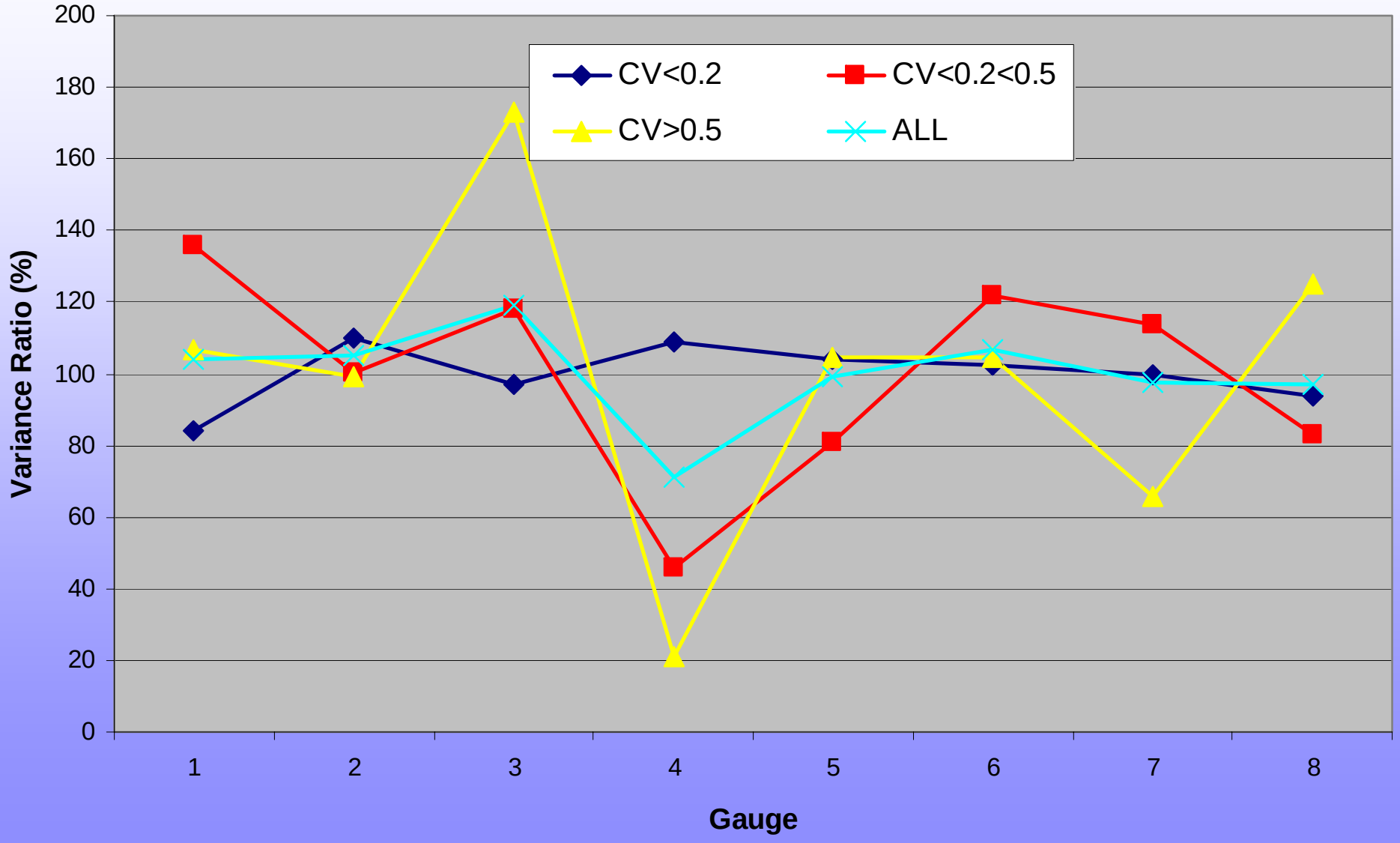
In next slides I break up plots to increase visibility



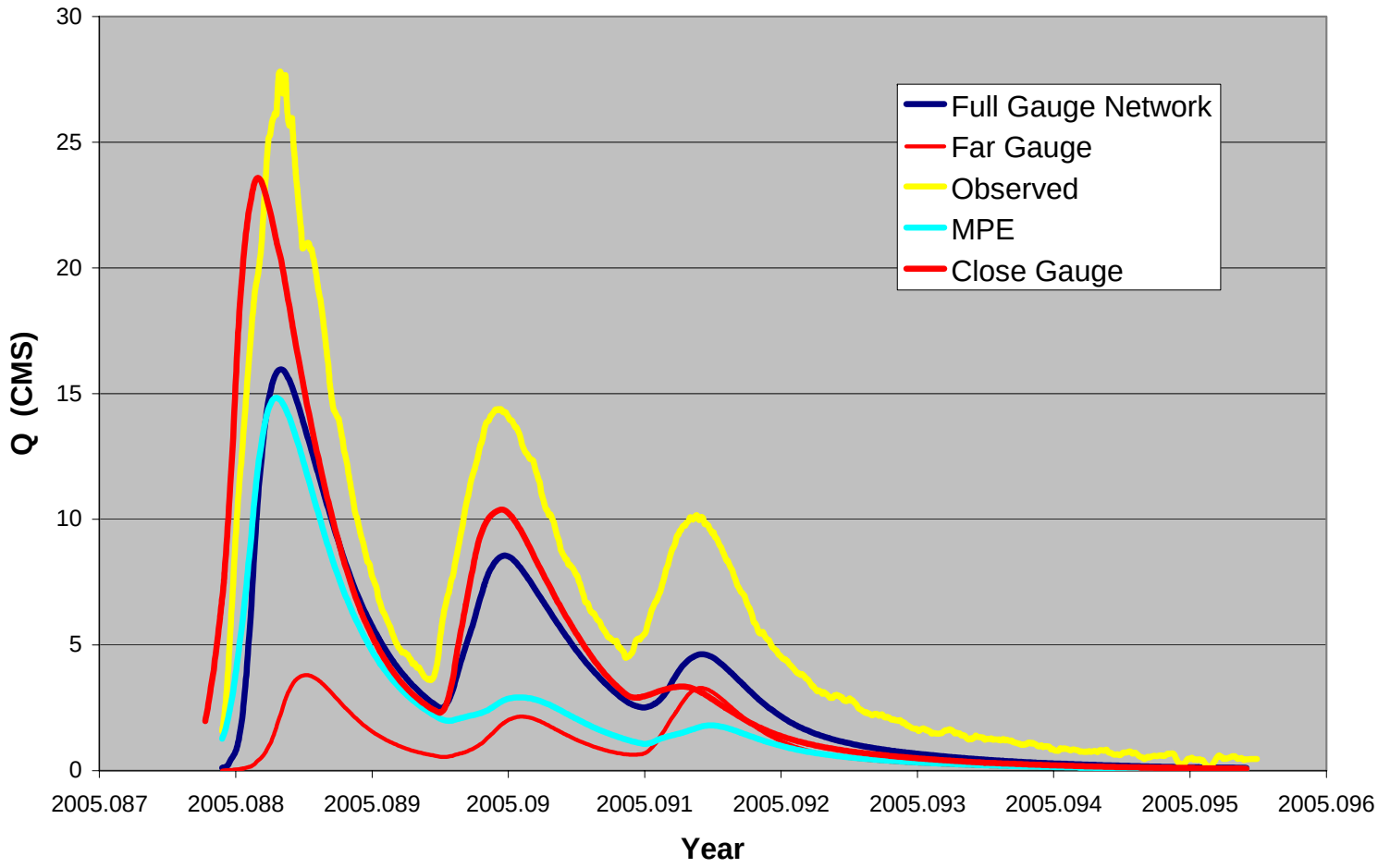

Mean Rainfall (mm)
2004
2005
2006
Normalized Bias
Normalized RMSE
Month


Correlation
1
0.9
0.8
0.7
0.6
1
2
3
4
5
6
7
8
9
10
11
12
2004
2005
2006
Efficiency
1
0.5
0
-0.5
-1
Month

Var(MPE-True)' / Var(MPE-True)



Period 4

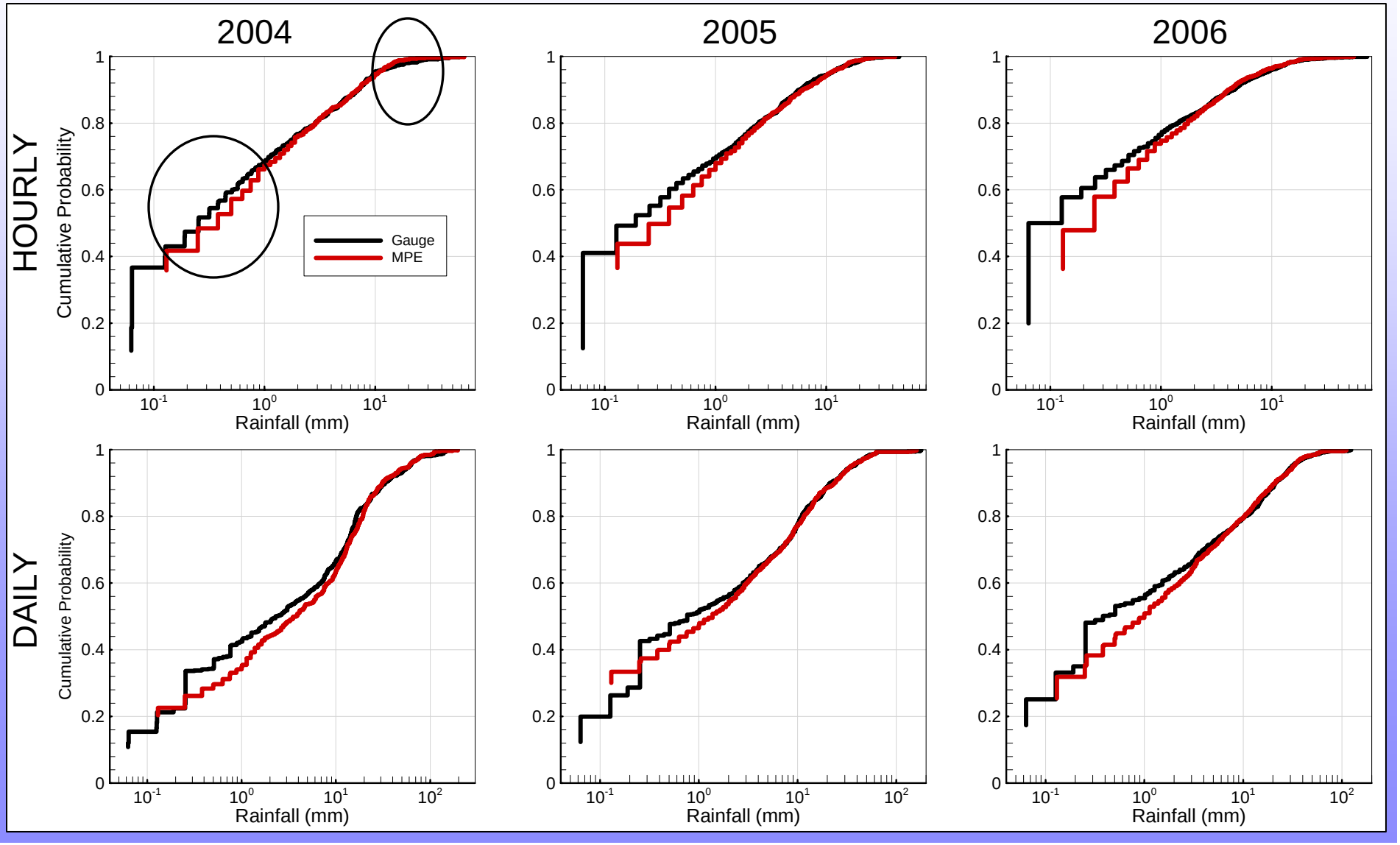

30
25
20
15
10
5
0
Q (CMS)
2005.087
2005.088
2005.089
2005.09
2005.091
2005.092
2005.093
2005.094
2005.095
2005.096
Year
Full Gauge Network
Far Gauge
Observed
MPE
Close Gauge

Validation Metrics

- Point- or grid-based methods

  - Continuous metrics
  - Categorical metrics
  - Distribution-oriented metrics
  - Spatial/Temporal Structure- metrics
  - Intensity stratification

Cumulative Distribution Function



Var(G-True) / Var(MPE-G)