Validation of Satellite-based Rainfall Estimation over the Limpopo Basin

By

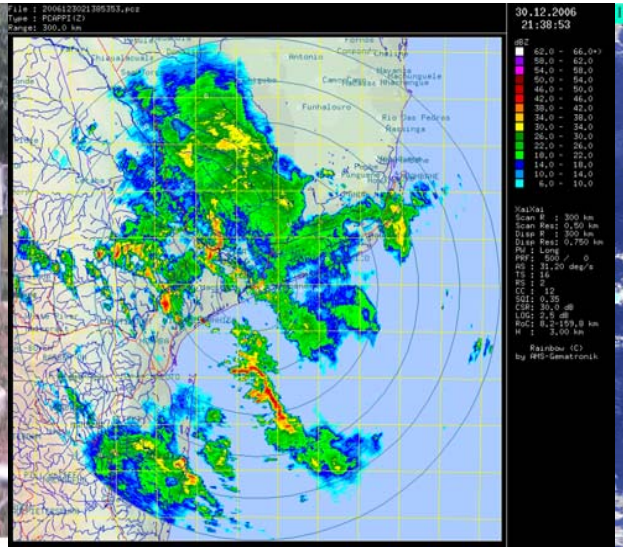
Mussa Mustafa

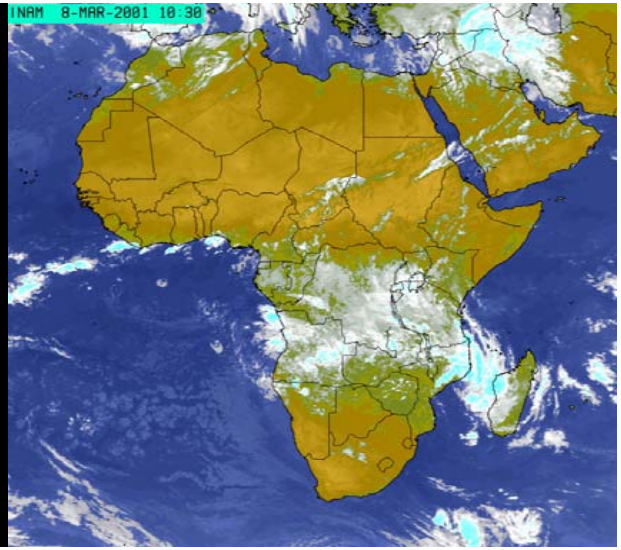
IPWG / PEHRPP Workshop
WMO Headquarter - Geneva,
3 – 5 December 2007

Presentation Outline

1. Introduction
2. Objectives of the study
3. Methodology
4. Results and discussion
5. Conclusions
6. Recommendations

Acknowledgment





- **Rain gauge – true point rain measurement, but is associated to many errors and is sparsely distributed;**
- **Radar – excellent space/time resolution and observation in real time, however, it requires infrastructures that are expensive;**
- **Satellite – good spatial/temporal resolution (3 - 5 km/15 - 30min for geostat. Sat.), samples oceans and remote regions.**

2. Objectives of the Study

Main objective:

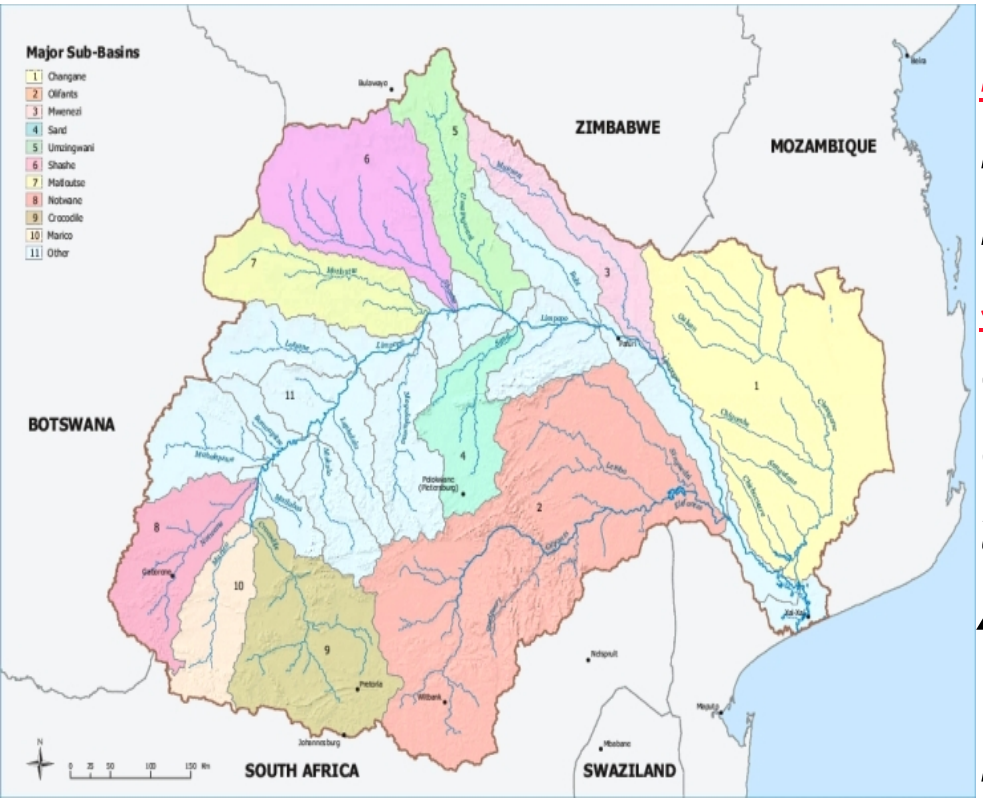
- to investigate the use of satellite rainfall estimation methods over the Limpopo basin.

Specific objectives were:

- To carry out literature survey of existing methods of rainfall estimation using satellites;
- To Generate daily rainfall estimates over the Limpopo basin using satellite based rainfall estimation methods, and
- To validate the satellite based rainfall estimates over the Limpopo basin.

3. Methodology

3.1 Description of the study area



Limpopo basin

Latitude: 20 – 25^0 S and

Longitude: 25 – 35^0 E

Southern summer

October to March

Climate: semi-arid to tropical temperate

Aver. Temp.: Max: 30 – 34^0 C

Min: 18 – 22^0 C

Precipitation:200 – 1500 mm

3.2 Satellite rainfall methods used in the study

3.2.1. Climate Prediction Centre Morphing (**CMORPH**) – estimates global precipitation by combining precipitation estimates derived from passive microwave observations and uses spatial propagation information from geostationary data.

Resolution: 30 min / 8 – km at equator;

Spatial coverage: 60^0 S to 60^0 N

3.2.2. Multiple Precipitation Analysis (**MPA**)
– is a combination of merged tropical rainfall measuring mission (TRMM) high quality microwaves and the variable rain rate infrared estimates.

Resolution: 3 hrs / 0.25 degrees

Spatial coverage:50^0 S to 50^0 N.

3.2.3. Precipitation Estimation from Remotely Sensed Information using Neural Network (**PERSIANN**) – is an merged estimation method that uses neural network function procedures to estimate rainfall.

- Resolution: 30 min / 0.25 degrees
- Global coverage: 50^0 S to 50^0 N.

3.2.4 Naval Research Laboratory Blended (**NRLB**) – is based upon statistical relationships derived from a precise, near real-time ensemble of collocated passive microwave and infrared data.

- Resolution: 3 hrs / 0.1 degrees
- Global coverage: 50^0 S to 50^0 N

3.3 Source of satellite data

Satellite	Type of data	Sensor	Algorithms
Meteosat - 8 (MSG)	IR	SEVIRI	CMORPH, MPA, NRLB and PERSIANN
GOES (9, 10, 12)	IR	VISSR	CMORPH, MPA, NRLB and PERSIANN
NOAA (15, 16, 17,)	PMW	AMSU-B	CMORPH, MPA, NRLB and PERSIANN
DMSP (13, 14, 15)	PMW	SSMI	CMORPH and MPA
TRMM	PMW	TMI	CMORPH, MPA and PERSIANN
Aqua	PMW	AMSR-E	CMORPH and MPA

3.4 Source of rain gauge data

Rain gauge data were obtained from Weather Services of Botswana, Mozambique, South Africa and Zimbabwe (total 90 rain gauge), for 1 October 2005 to 31 March 2006.

3.5 Validation of Satellite Rainfall Estimates

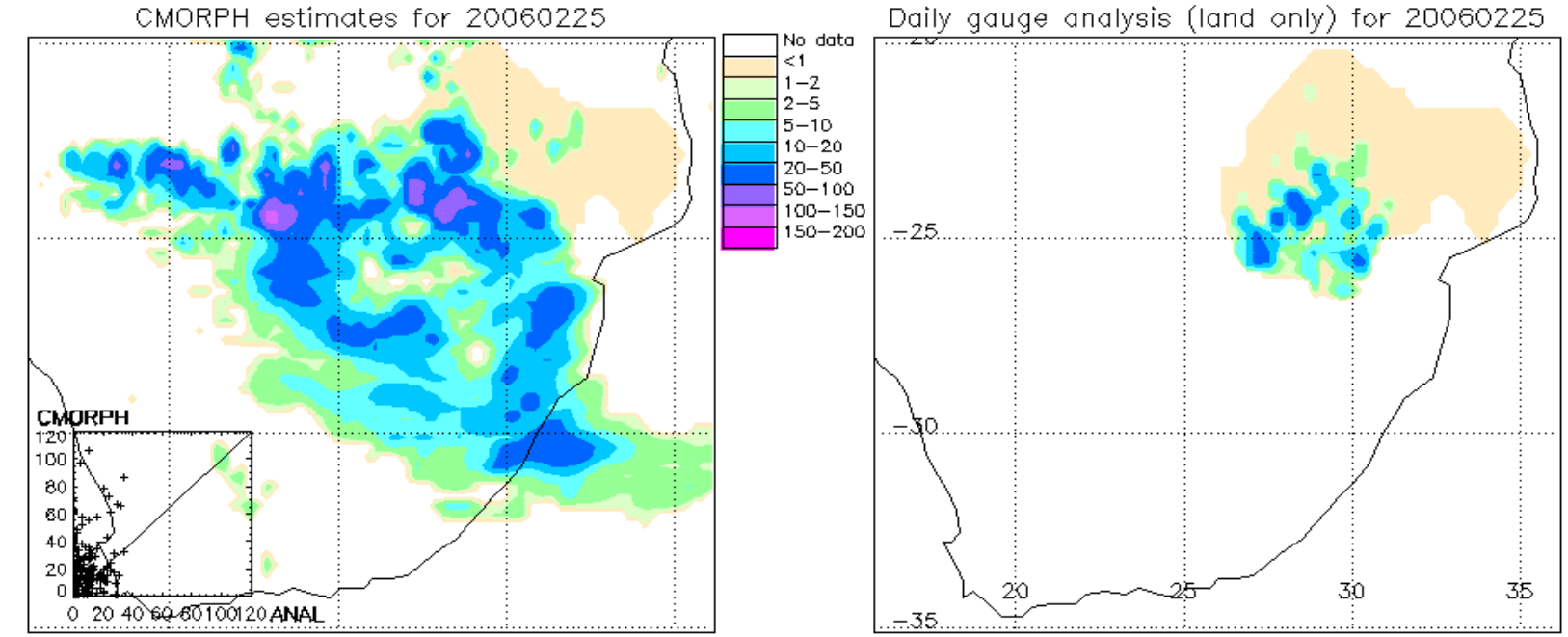
- Rainfall data was averaged into grid boxes of 0.25 x 0.25 degrees resolution, using the inverse-weighting interpolation method;

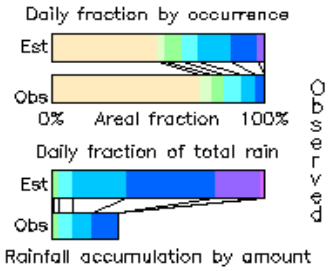
- The satellite estimates were developed using 0.25 degree resolution;

- A surface mask was used over the Limpopo basin;
- A variety of statistical parameters were used to measure different aspects of algorithm quality (bias, absol. error, rmse, POD, FAR, ETS, HKS, HSS, and CSI).

		Event estimated		Total obser.
		Yes	No	
Event Obse	Yes	h (hits)	f (false alarm)	h + f
	No	m (misses)	z (correct negative)	m + z
	Total estimated	h+m	f+z	h + f + m + z

4. Results and discussion





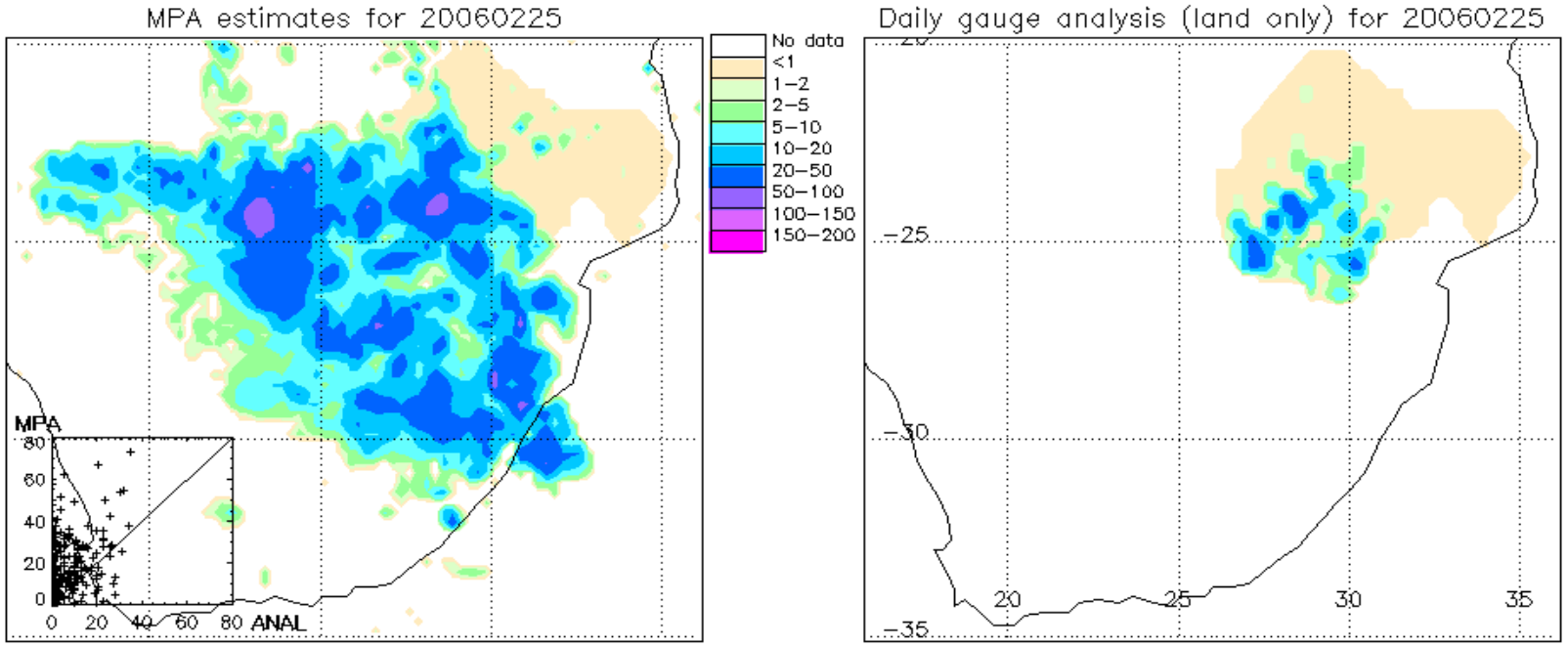
Observed \ CMORPH	<1	≥1
<1	291	131
≥1	12	172

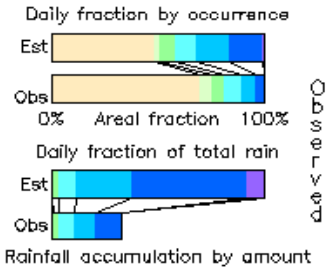
Verification statistics for 20060225 n=606 Verif. grid=0.25° Units=mm/d

	Analysed	CMORPH
# gridpoints raining	184	303
Average rain	2.8	8.9
Conditional rain	9.2	17.8
Rain volume (mm*km²x10⁶)	1.2	3.7
Maximum rain	34.6	106.3

Mean abs error = 7.2
RMS error = 14.9
Correlation coeff = 0.434
Frequency bias = 1.647
Probability of detection = 0.935
False alarm ratio = 0.432
Hanssen & Kuipers score = 0.624
Equitable threat score= 0.359

MPA





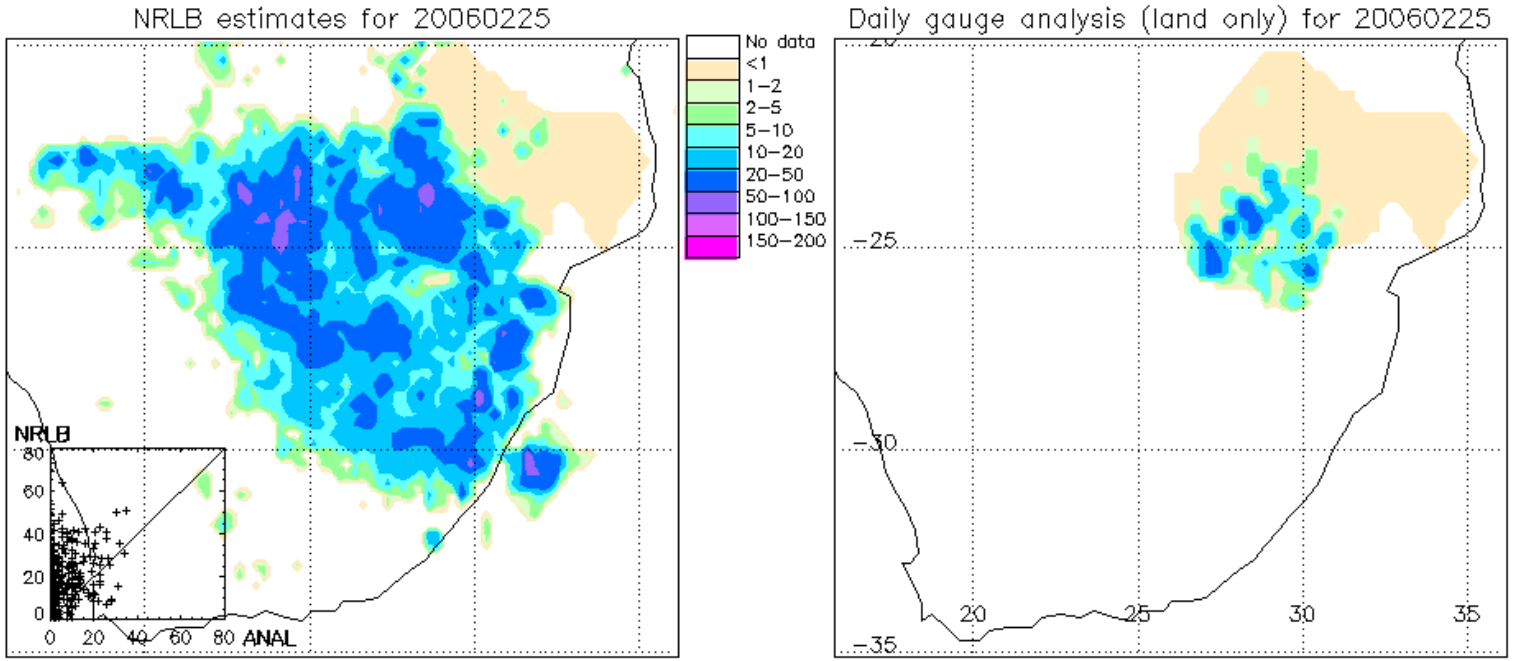
Observed \ MPA	<1	≥1
<1	290	132
≥1	6	178

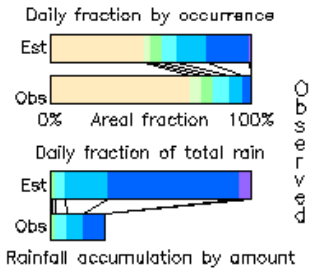
Verification statistics for 20060225 n=606 Verif. grid=0.25° Units=mm/d

	Analysed	MPA
# gridpoints raining	184	310
Average rain	2.8	8.5
Conditional rain	9.2	16.6
Rain volume (mm*km²x10⁶)	1.2	3.5
Maximum rain	34.6	73.4

Mean abs error = 6.4
RMS error = 12.0
Correlation coeff = 0.520
Frequency bias = 1.685
Probability of detection = 0.967
False alarm ratio = 0.426
Hanssen & Kuipers score = 0.655
Equitable threat score= 0.378

NRLB





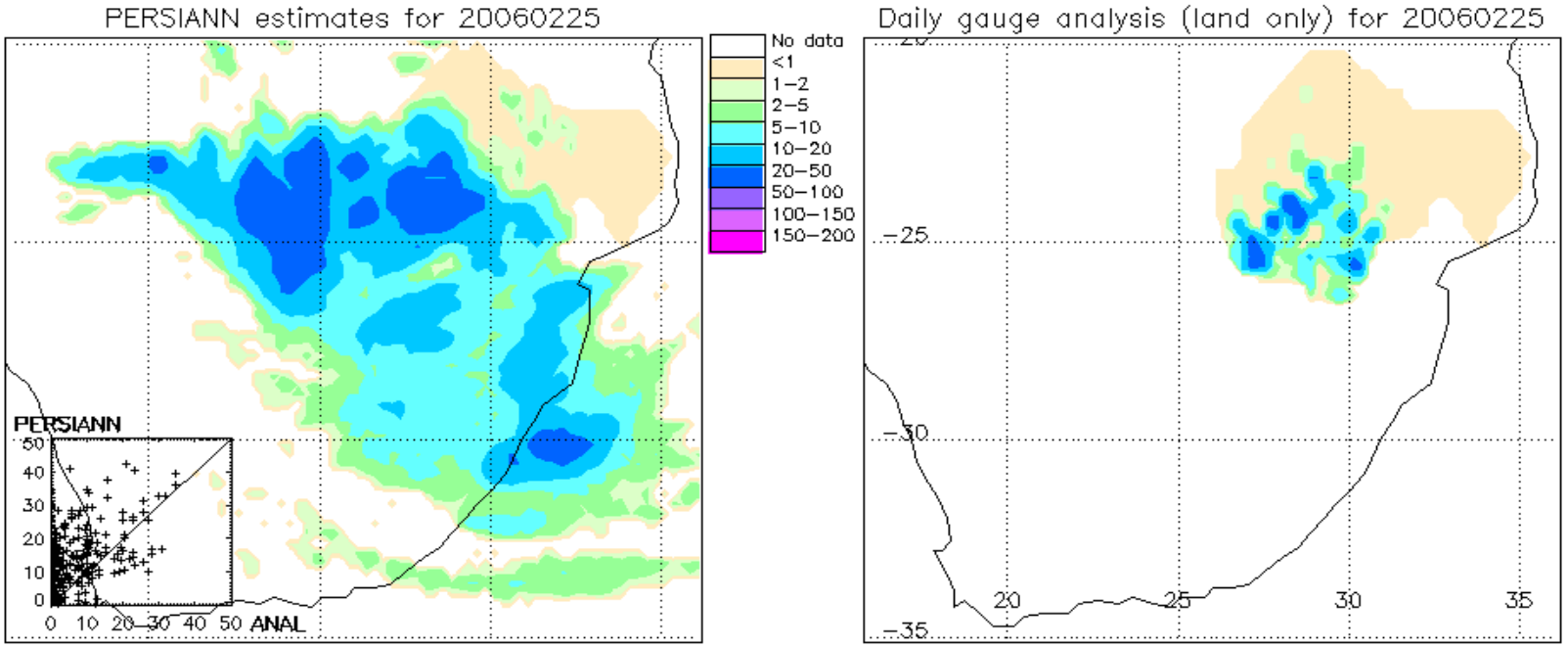
Observed \ NRLB	<1	≥1
<1	276	146
≥1	10	174

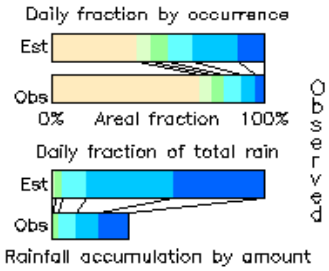
Verification statistics for 20060225 n=606 Verif. grid=0.25° Units=mm/d

	Analysed	NRLB
# gridpoints raining	184	320
Average rain	2.8	10.2
Conditional rain	9.2	19.3
Rain volume (mm*km²x10⁶)	1.2	4.2
Maximum rain	34.6	72.9

Mean abs error = 8.1
RMS error = 14.5
Correlation coeff = 0.424
Frequency bias = 1.739
Probability of detection = 0.946
False alarm ratio = 0.456
Hanssen & Kuipers score = 0.600
Equitable threat score= 0.330

PERSIANN





Observed \ PERSIANN	<1	≥1
<1	243	179
≥1	4	180

Verification statistics for 20060225 n=606 Verif. grid=0.25° Units=mm/d

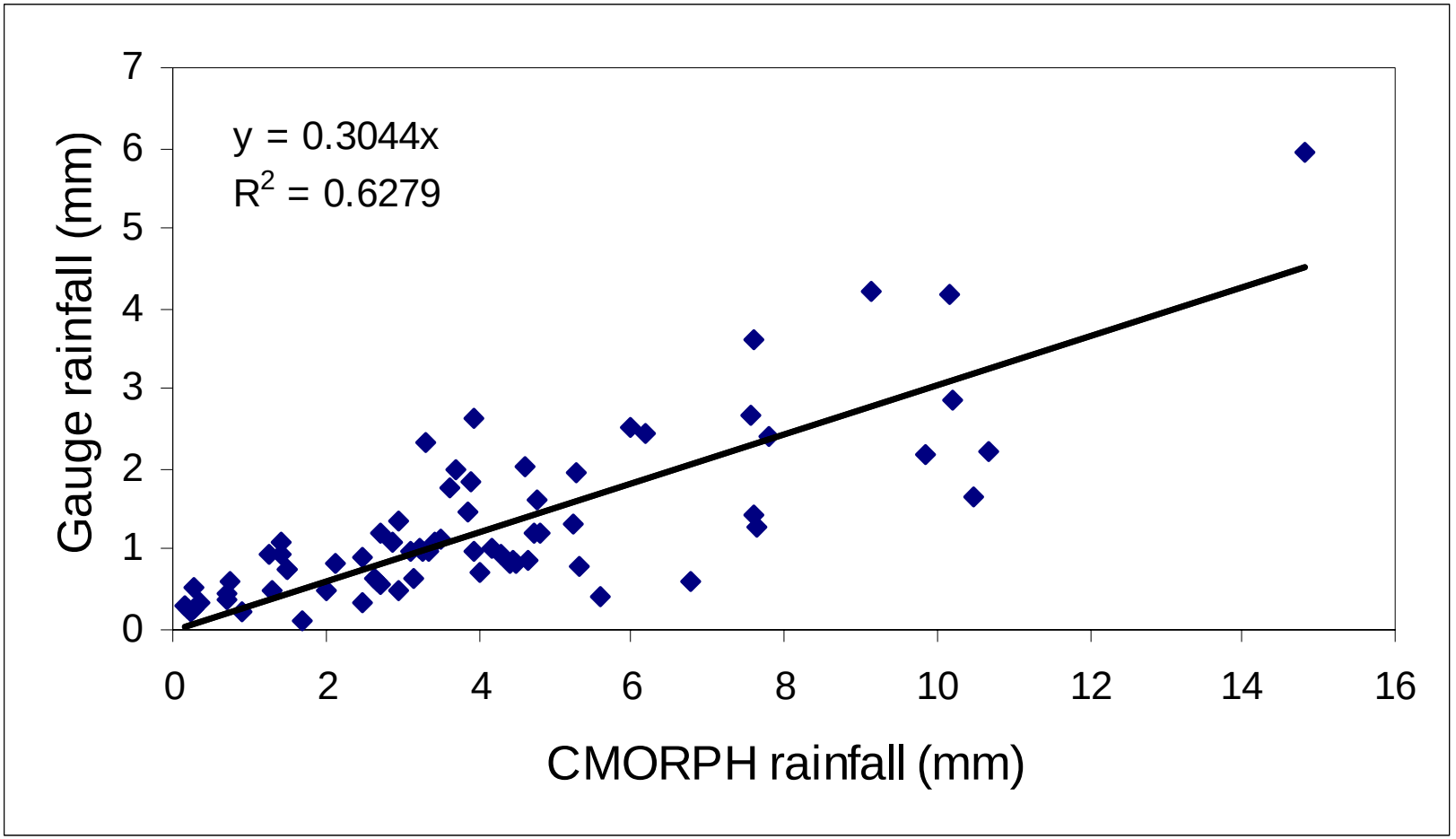
	Analysed	PERSIANN
# gridpoints raining	184	359
Average rain	2.8	7.7
Conditional rain	9.2	12.9
Rain volume (mm*km²x10⁶)	1.2	3.2
Maximum rain	34.6	42.3

Mean abs error = 5.6
RMS error = 9.3
Correlation coeff = 0.535
Frequency bias = 1.951
Probability of detection = 0.978
False alarm ratio = 0.499
Hanssen & Kuipers score = 0.554
Equitable threat score= 0.280

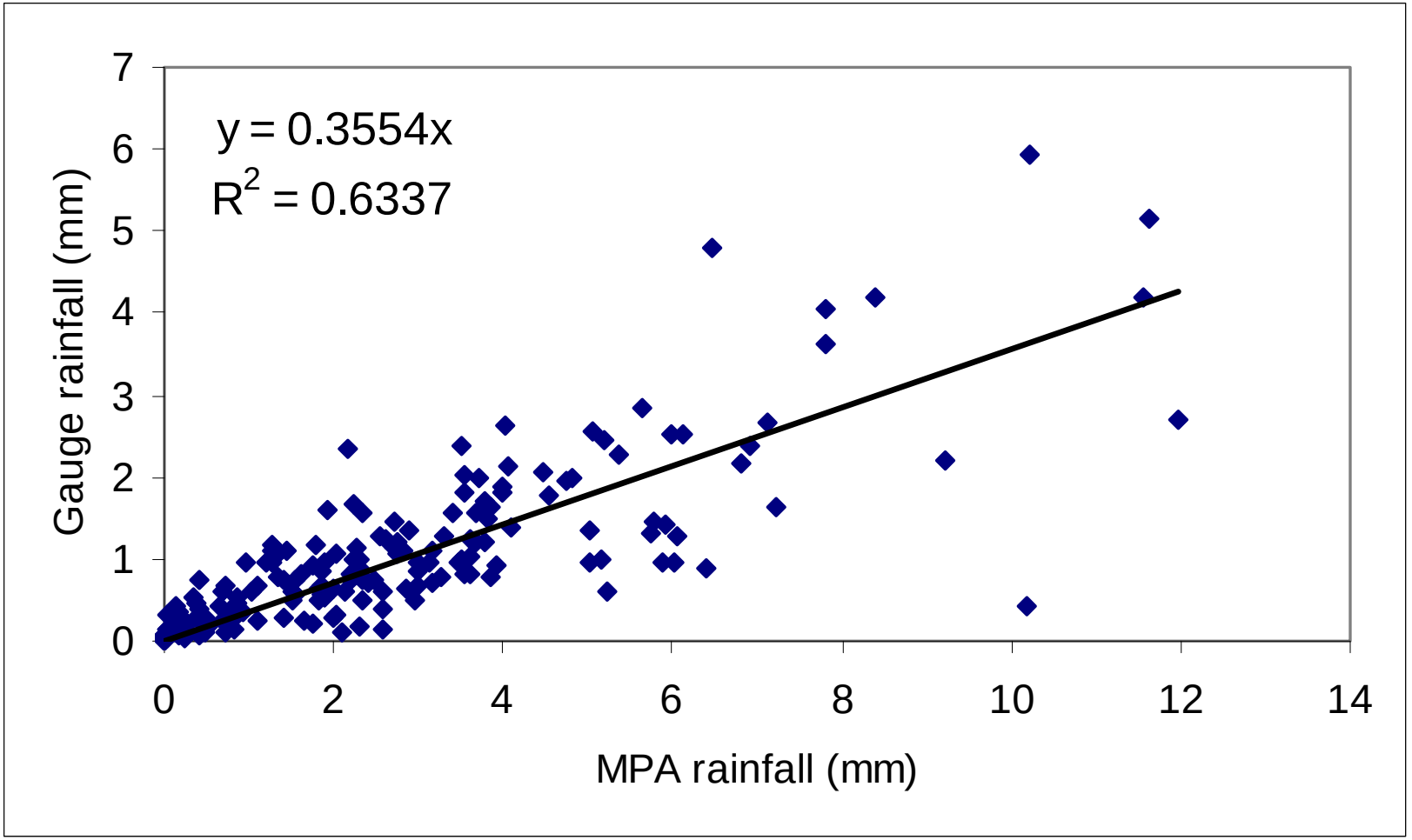
Summary of some statistical parameters for 25 February 2006

Algorithms	Rmse	Bias	POD	FAR	HKS	ETS
CMORPH	14.9	1.6	0.90	0.43	0.62	0.36
MPA	12.0	1.1	0.97	0.43	0.65	0.38
NRLB	14.5	1.7	0.95	0.46	0.60	0.33
PERSIANN	9.3	1.9	0.98	0.50	0.55	0.28

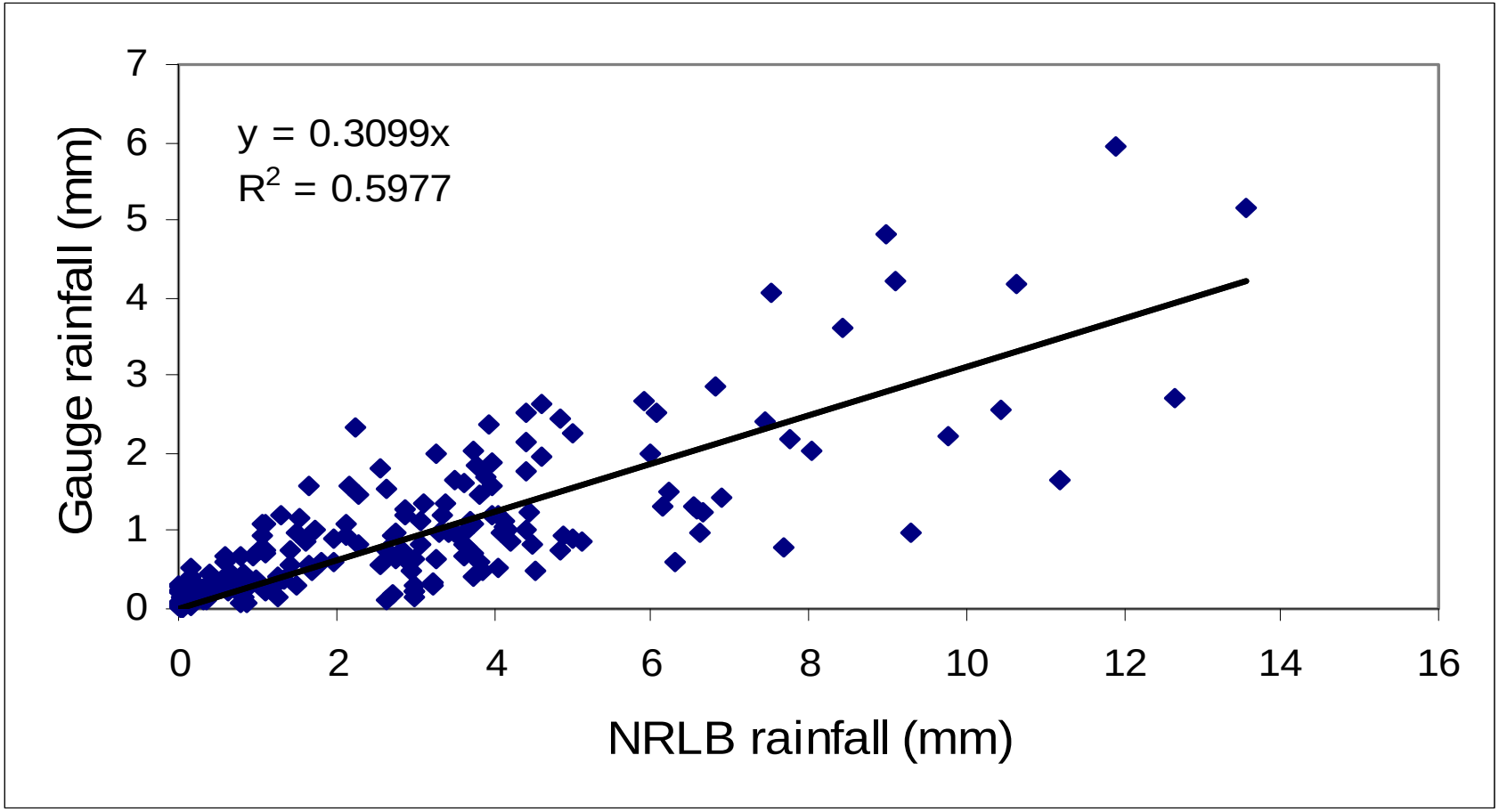
4.1 Comparison between satellite estimates and gauge rainfall



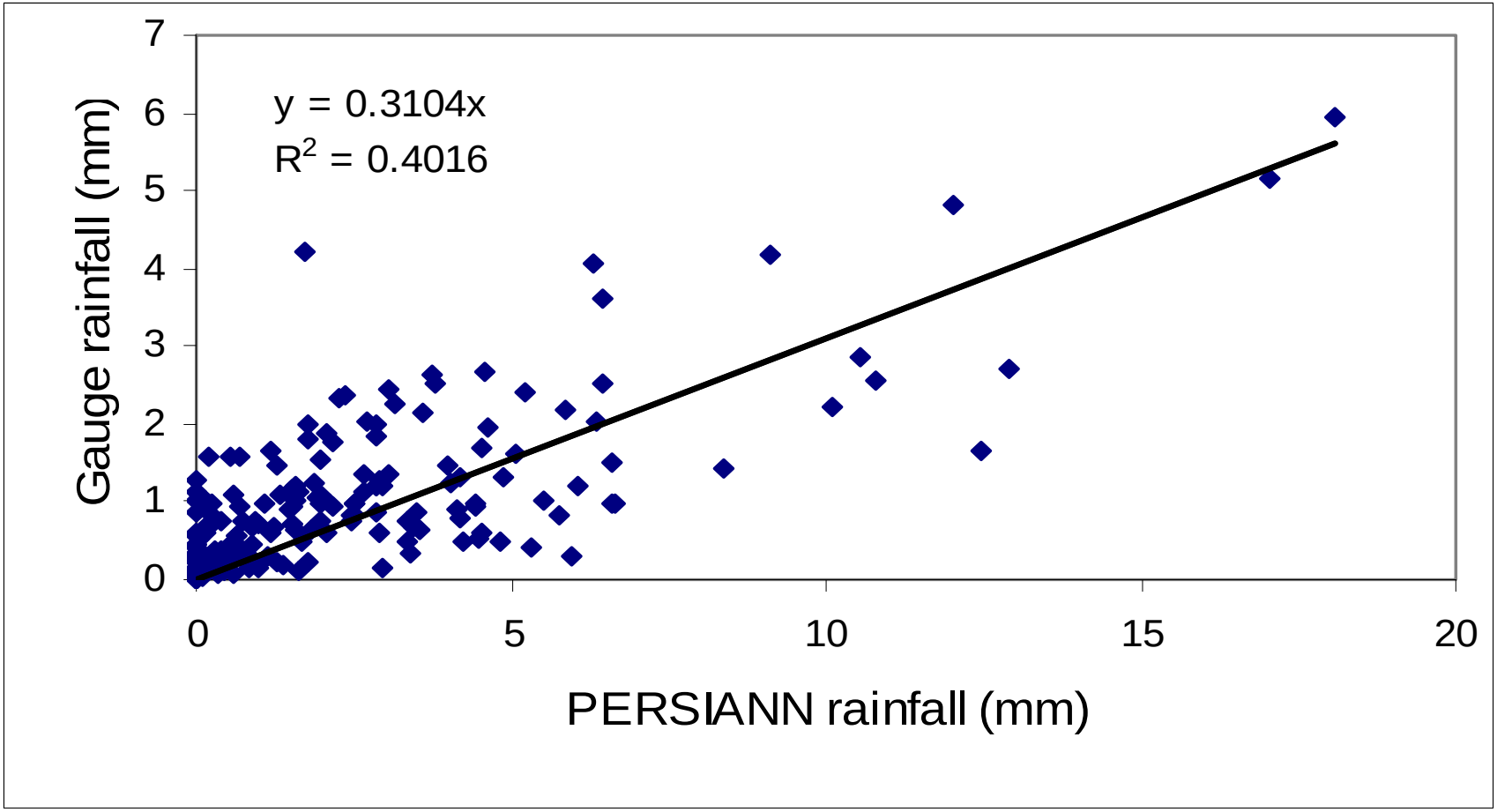
Gauge - MPA


y = 0.3554x
R2 = 0.6337
Gauge rainfall (mm)
MPA rainfall (mm)
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
14

Gauge - NLRB


y = 0.3099x
R2 = 0.5977
Gauge rainfall (mm)
NRLB rainfall (mm)
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
14
16

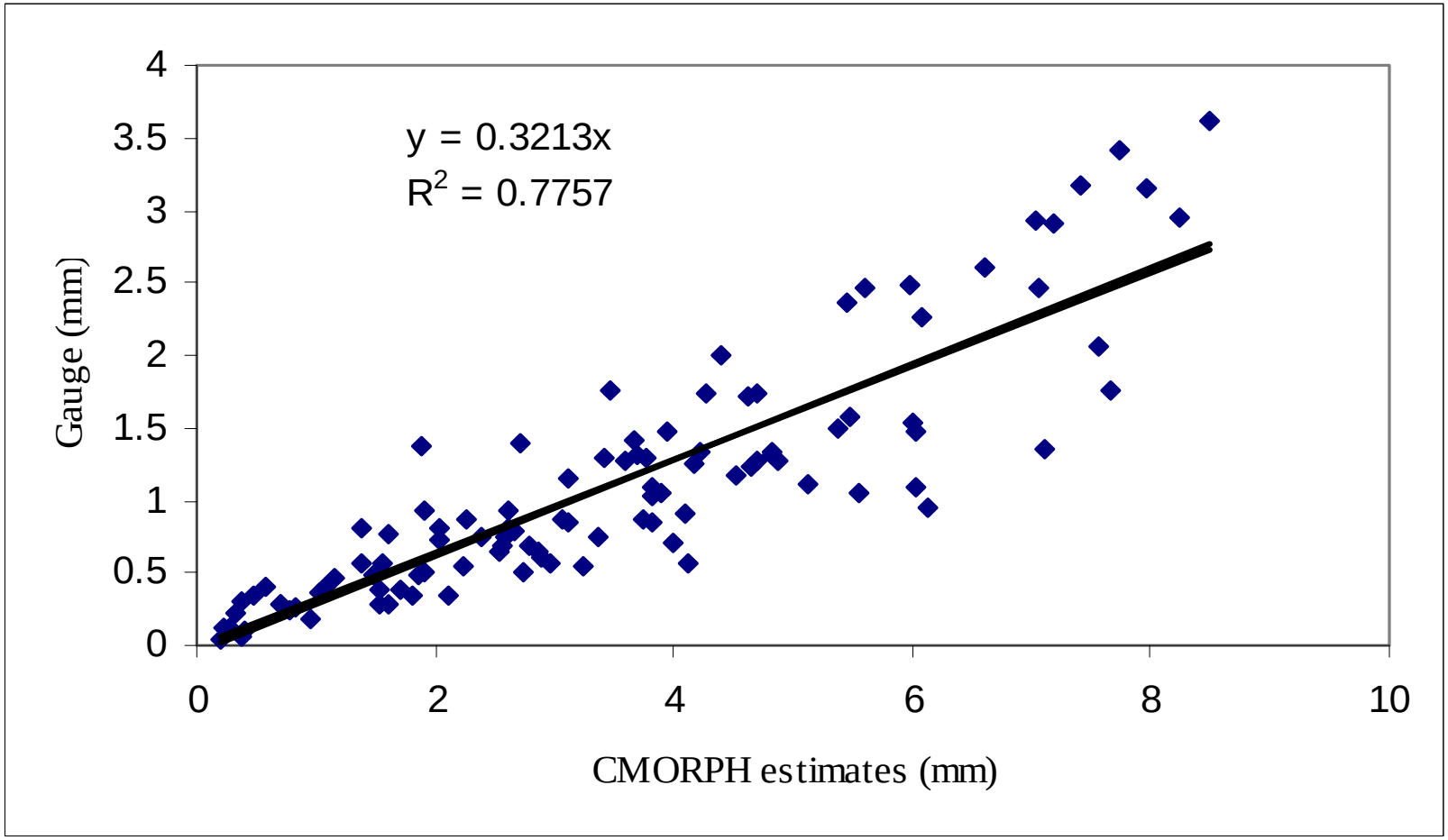
Gauge - PERSIANN

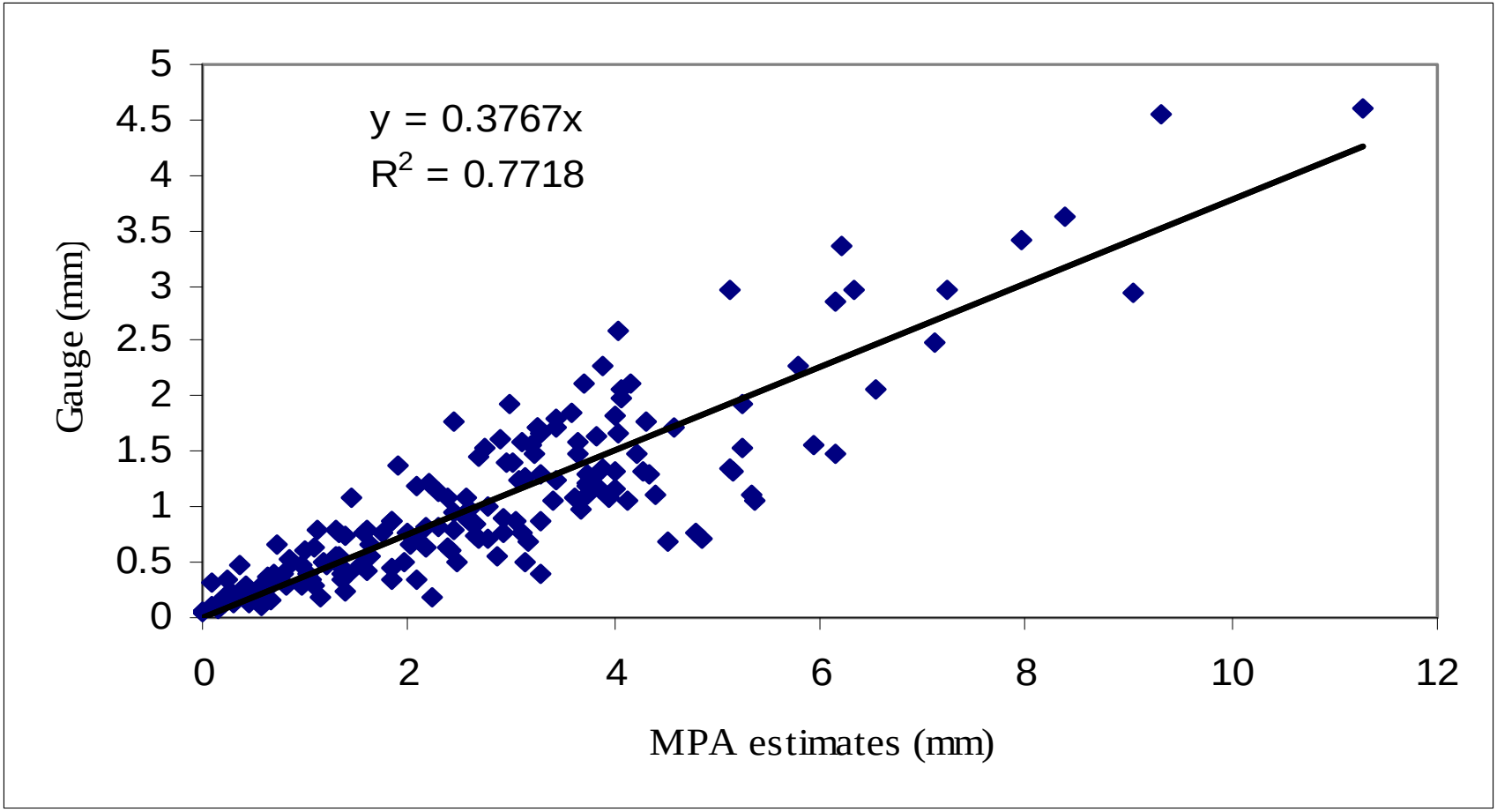


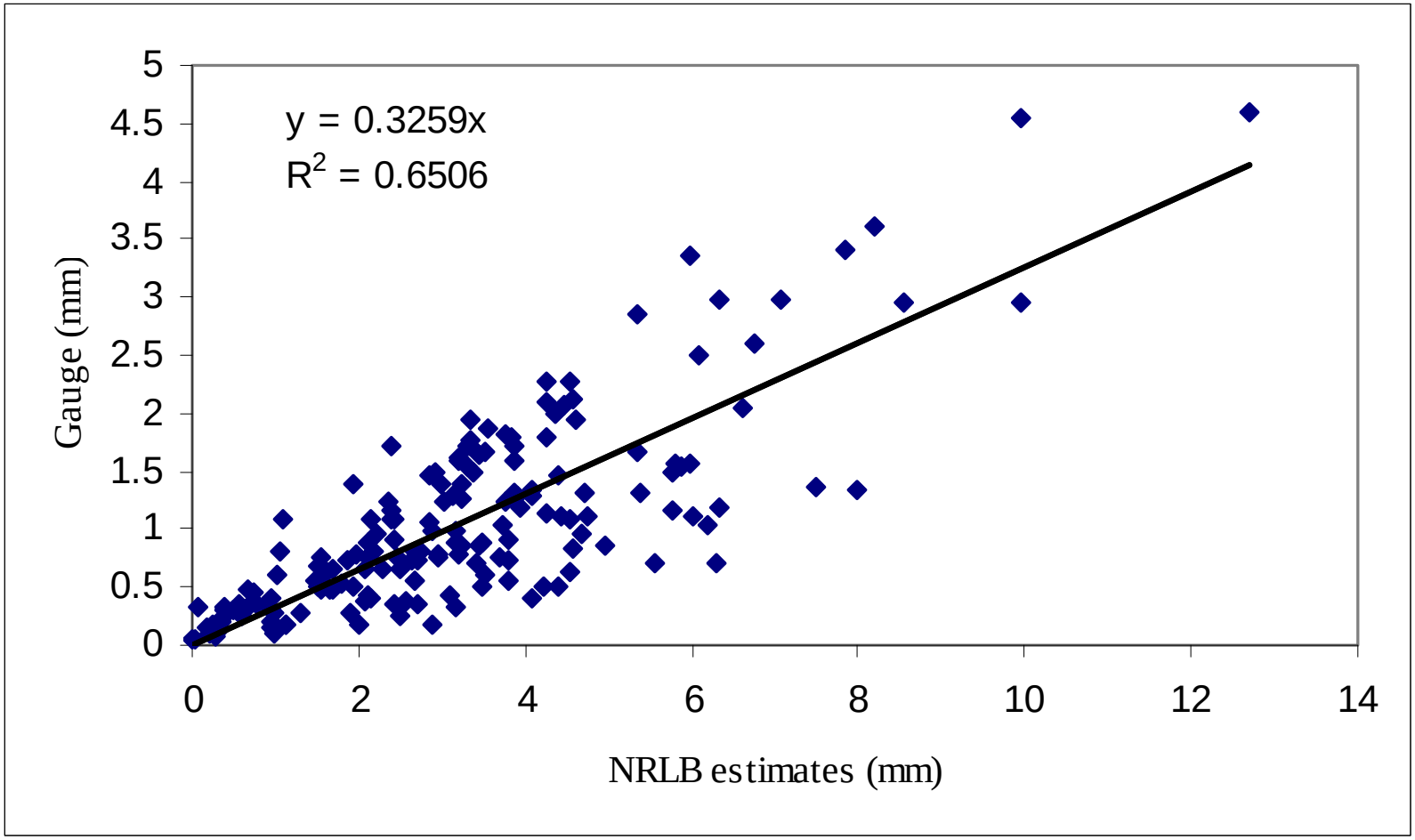
Summary of some statistical parameters for the 2005 / 2006 rainfall season

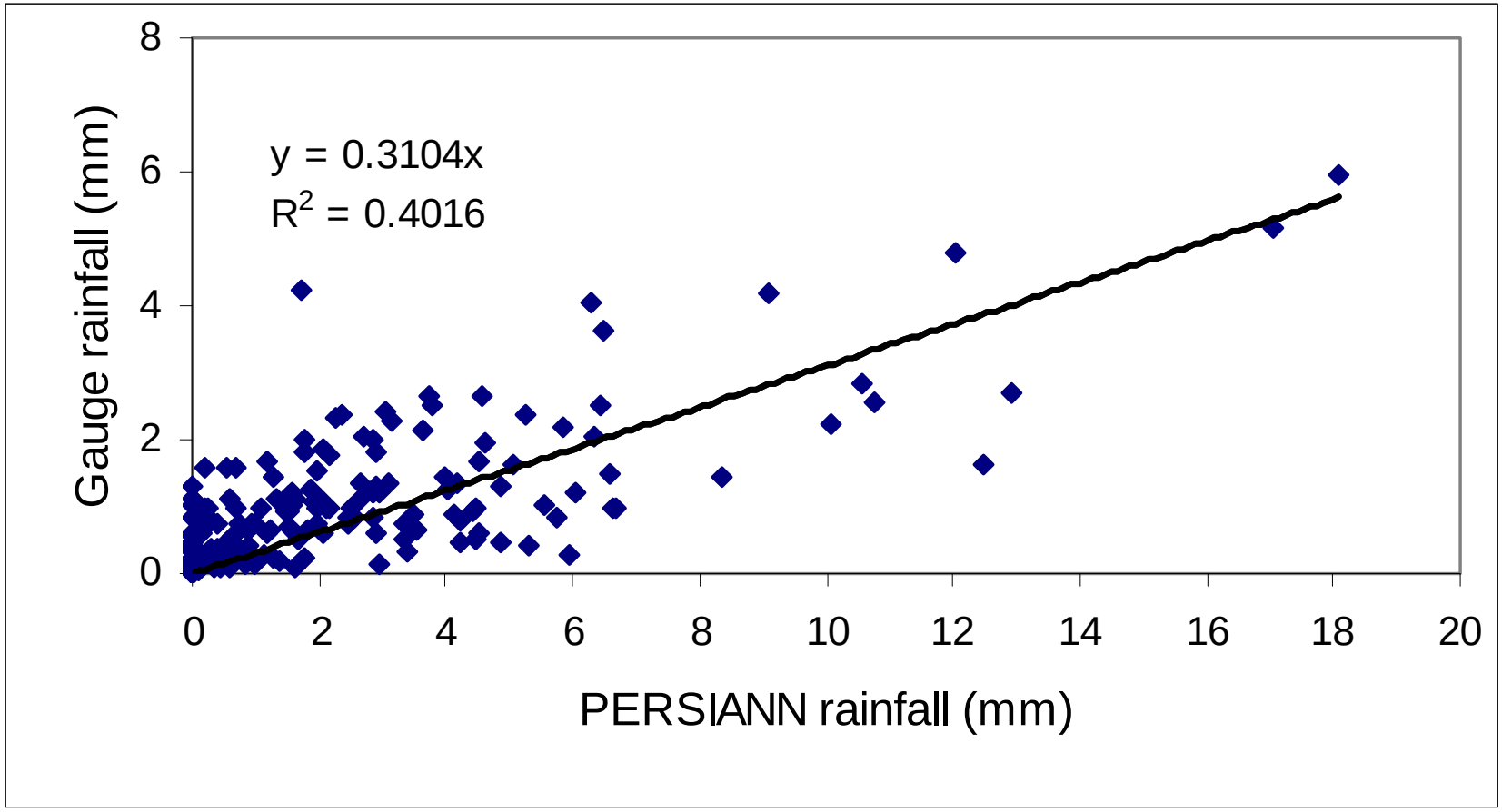
Method	Mean absolute error (mm/day)	Rmse (mm/day)	Bias	R^2
MPA	5.2	6.9	0.4	0.6337
CMORPH	3.6	7.3	0.3	0.6279
NRLB	3.3	8.9	0.3	0.5977
PERSIANN	2.5	5.5	0.3	0.4016

4.2 Comparison between three-daily moving area average and gauge data




y = 0.3767x
R2 = 0.7718
Gauge (mm)
MPA estimates (mm)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
2
4
6
8
10
12

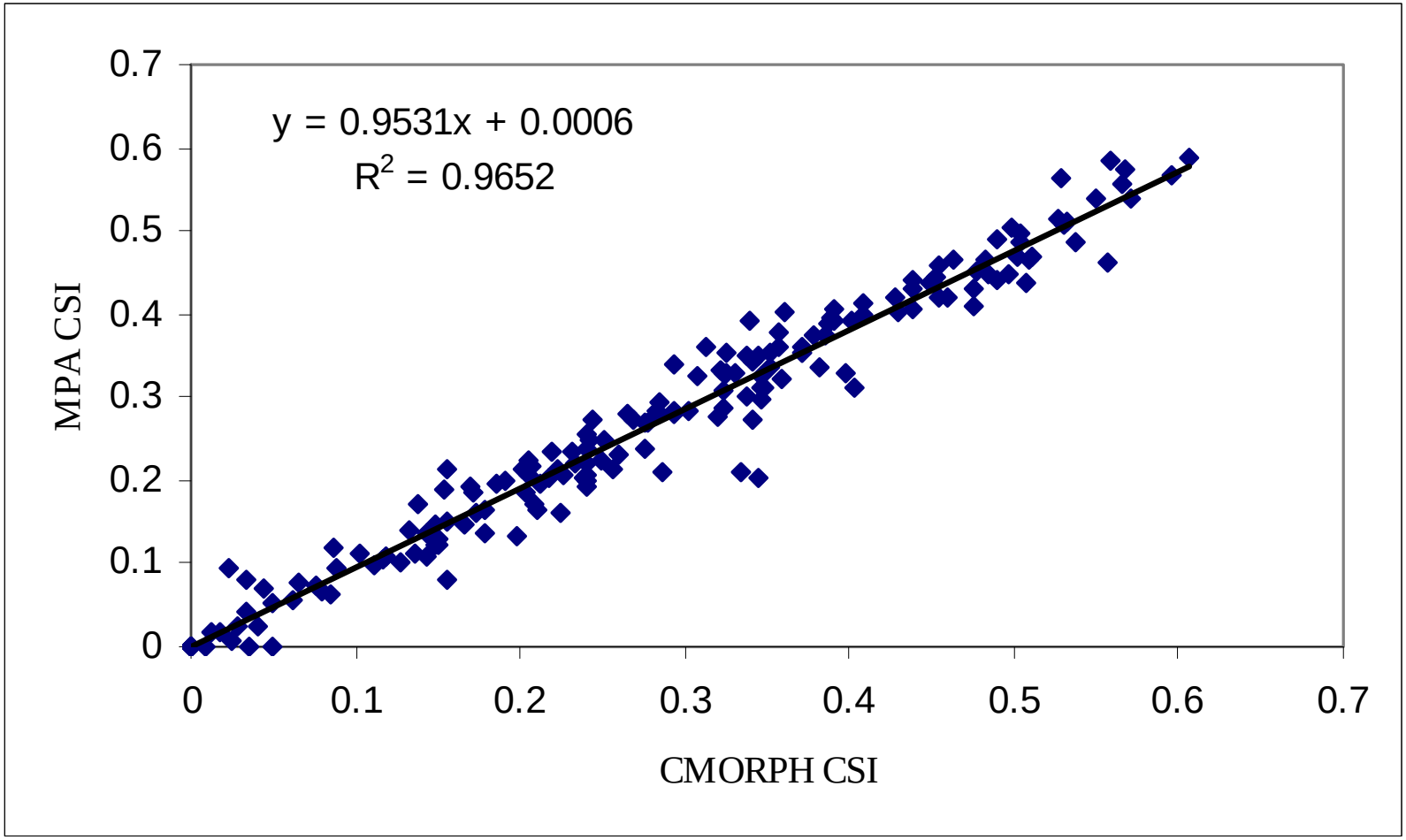

y = 0.3259x
R2 = 0.6506
Gauge (mm)
NRLB estimates (mm)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
2
4
6
8
10
12
14

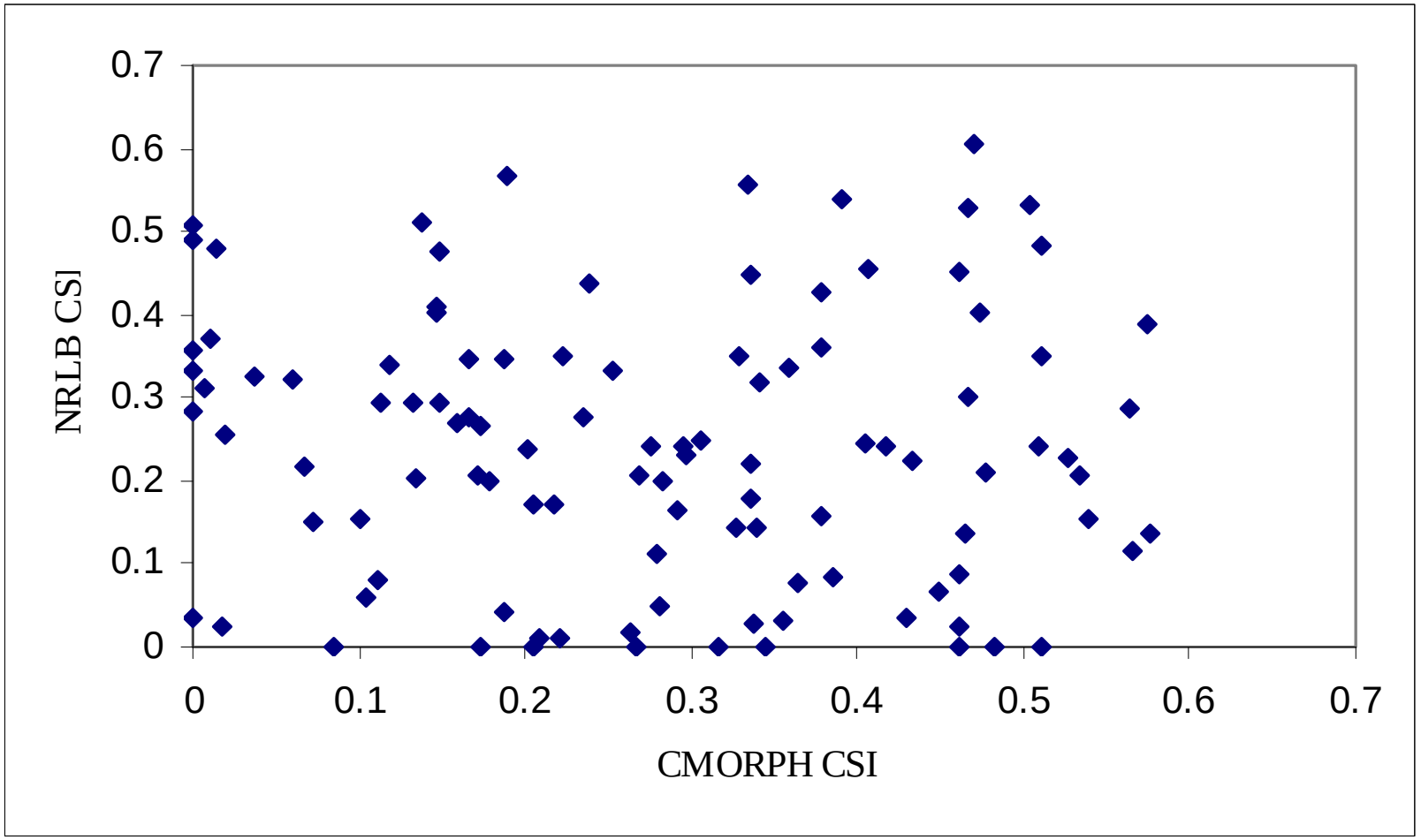

y = 0.3104x
R2 = 0.4016
Gauge rainfall (mm)
PERSIANN rainfall (mm)
0
2
4
6
8
10
12
14
16
18
20

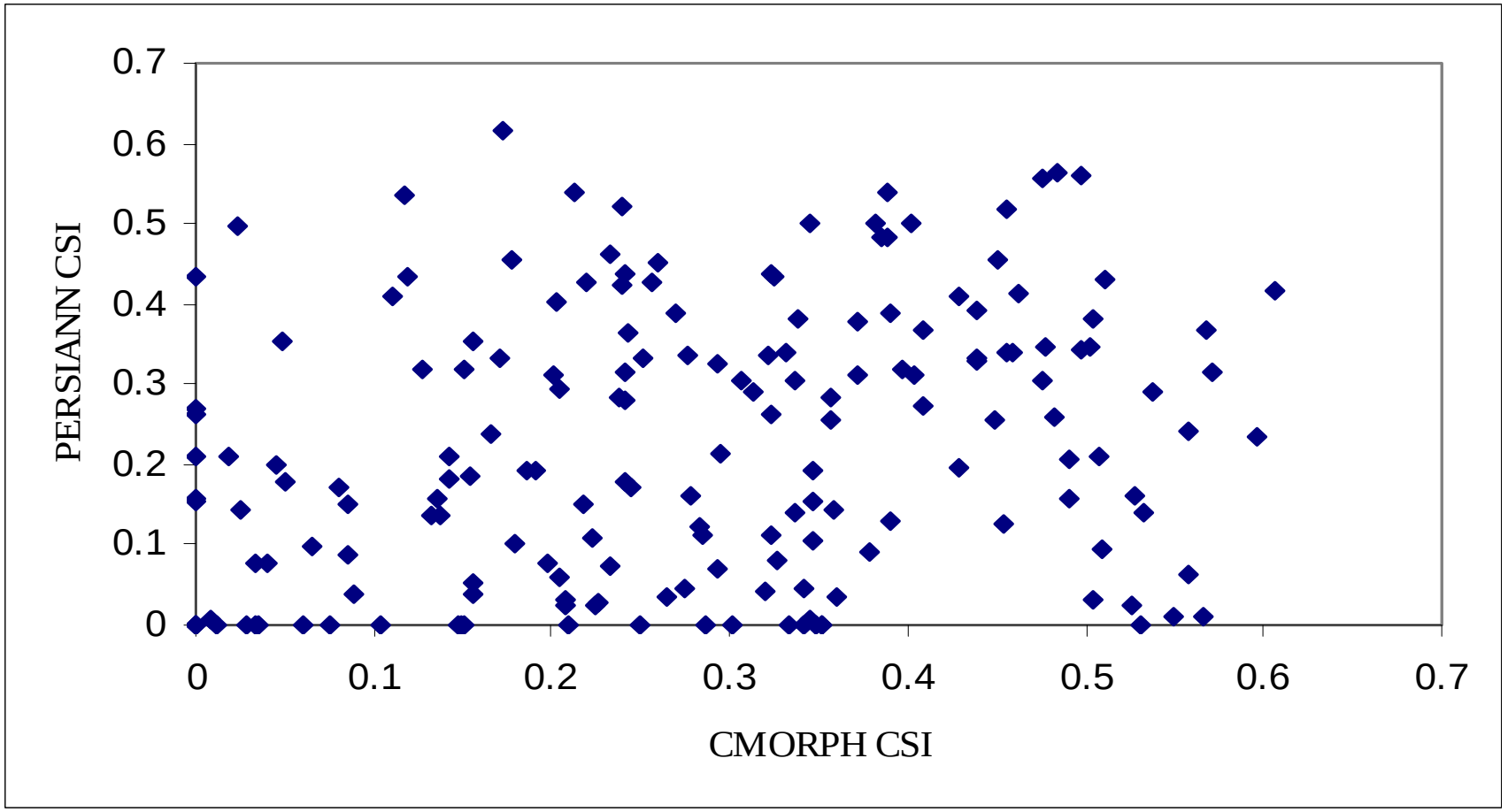
Summary of coefficients of determination

Method	R^2 before moving the daily area average rainfall	R^2 after three daily moving area average rainfall
CMORPH	0.6279	0.7757
MPA	0.6337	0.7718
NRLB	0.5977	0.6506
PERSIANN	0.4016	0.4226

4.3 Analysis of performance of the algorithms




0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
NRLB CSI
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
CMORPH CSI


0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
PERSIANN CSI
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
CMORPH CSI

Summary of statistical parameters for the estimation algorithms

Method	POD	FAR	ETS	HKS	HSS
CMORPH	0.91	0.19	0.90	0.29	0.28
MPA	0.89	0.17	0.88	0.26	0.26
PERSIANN	0.89	0.18	0.83	0.21	0.21
NRLB	0.76	0.17	0.60	0.23	0.19

5. Conclusions

- All four algorithms (CMORPH, MPA, PERSIANN and NRLB) showed skill in estimating rainfall and there was relatively good agreement between CMORPH, MPA and NRLB algorithms and fair agreement between PERSIANN and rain gauge (from the values of R-squared);

- CMORPH and MPA performed better than PERSIANN and NRLB, according to the critical success index;

- The accuracy of the algorithms increased with the time after moving three-daily area average gauge;

- All algorithms overestimated rainfall in quantity and spatially over the region with positive values of bias;

- The dry conditions experienced during the 2005 / 2006 rainfall season could have affected the quality of rain gauge data and contributed negatively to the validation of satellite based rainfall estimation algorithms.

6. Recommendations

- To improve the rainfall measurement infrastructures and data exchange within the Limpopo basin between the four countries;
- To carry out similar study during good rainfall season; and
- To validate rainfall estimation by combining gauge, radar and satellite.

Thank you

mussa_m@inam.gov.mz
Mobile: + 258 82 39 44 279
Fax: + 258 21 49 01 48

Acknowledgement

- International Precipitation Working Group
- World Meteorological organization
- South African Weather Service

- Dr. Joe Turk, Dr. George Huffman, Dr. John Janowiak and Dr. Ralph Ferraro

- Alice Blunt

End