



Validation of TRMM Satellite Data with Rain Gauge Data in Sindh Province, Pakistan

Presented by:

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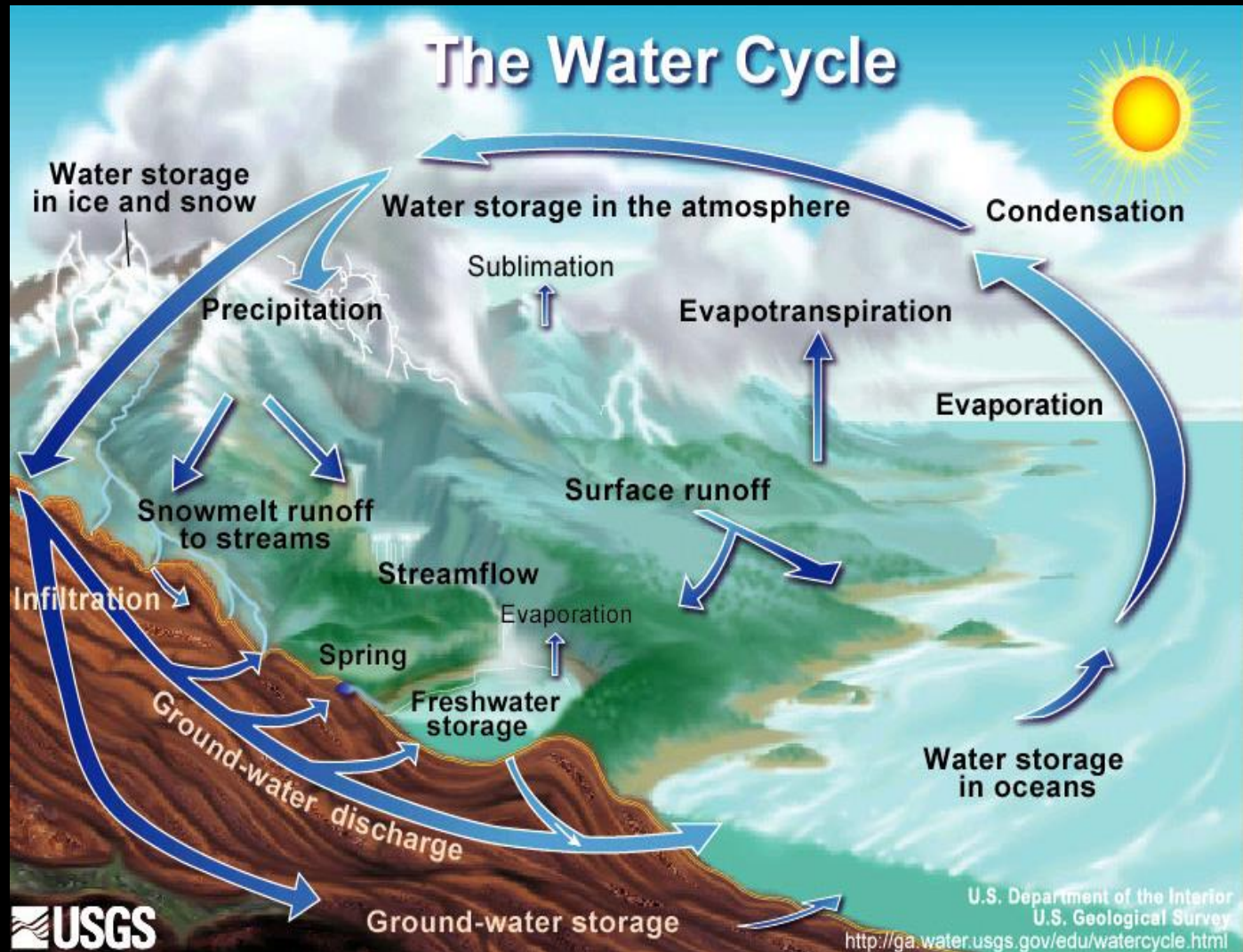


Presentation Outline

- Background
- Objectives
- Scope
- Study Area
- Methodology
- Results
- Conclusion

Background

- Water is Life...





Background

Standard Rain Gauge



Tipping Bucket Rain Gauge



Automatic Stations

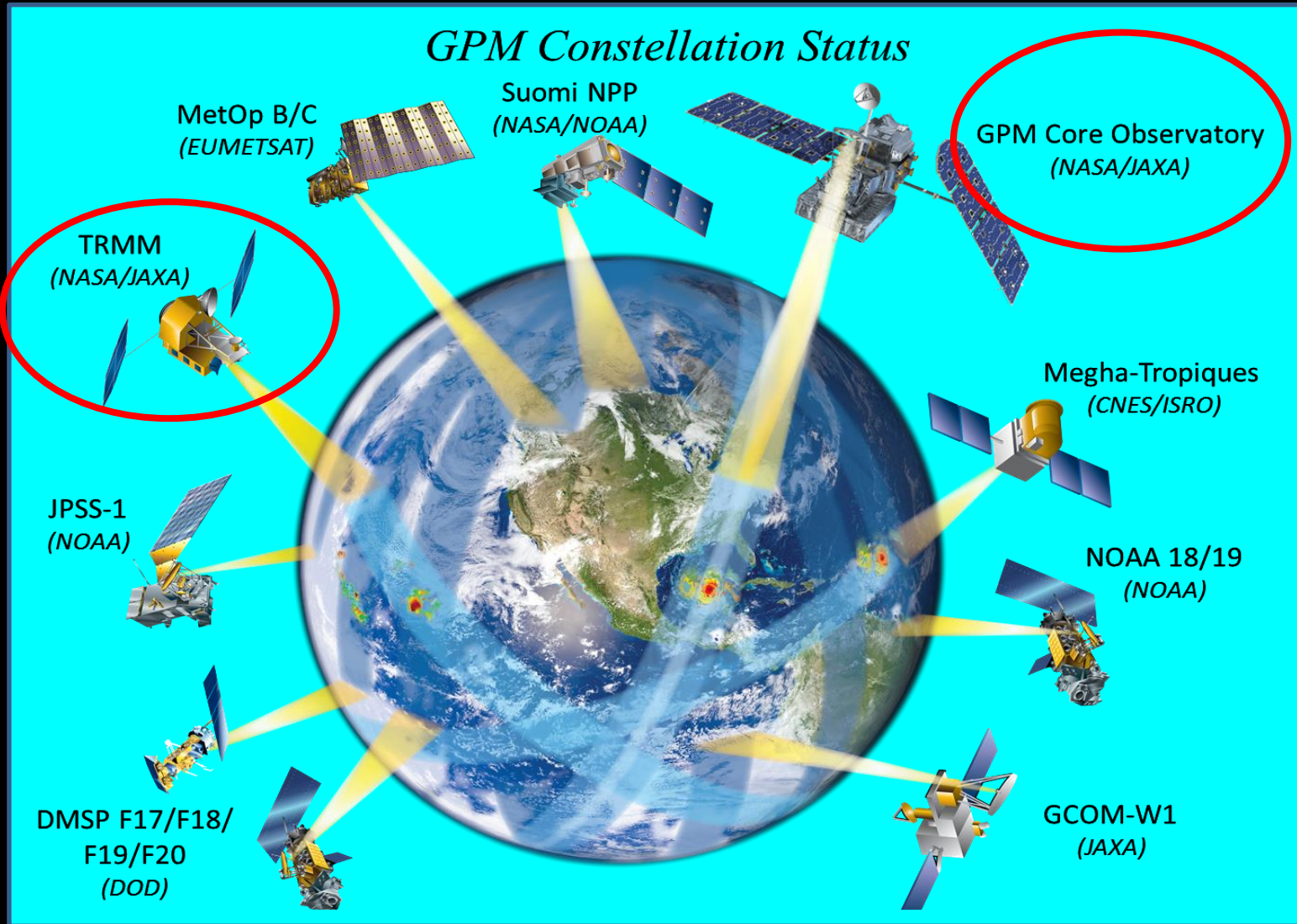


Background



Satellite Based Rainfall Quantity Measure

TRMM 3B42 (V6) product used to obtain





Objectives

- Determine the correlation between satellite rainfall estimates and rain gauges measurements
- Quantify the location specific anomalies between satellite and ground measurements at different temporal and spatial scales
- To evaluate the accuracy of TRMM rainfall estimates at the temporal scales of 12 hour (maximum), Daily, monthly, seasonal and annual

Scope



Agricultural

- Crop water requirement calculation
- Crop yield forecast modelling
- Agri-economic policy
- Crop Insurance



Hydrology

- Hydrological simulation & modelling
- Flood Forecasting/ Inundation Modelling
- Reservoir routing



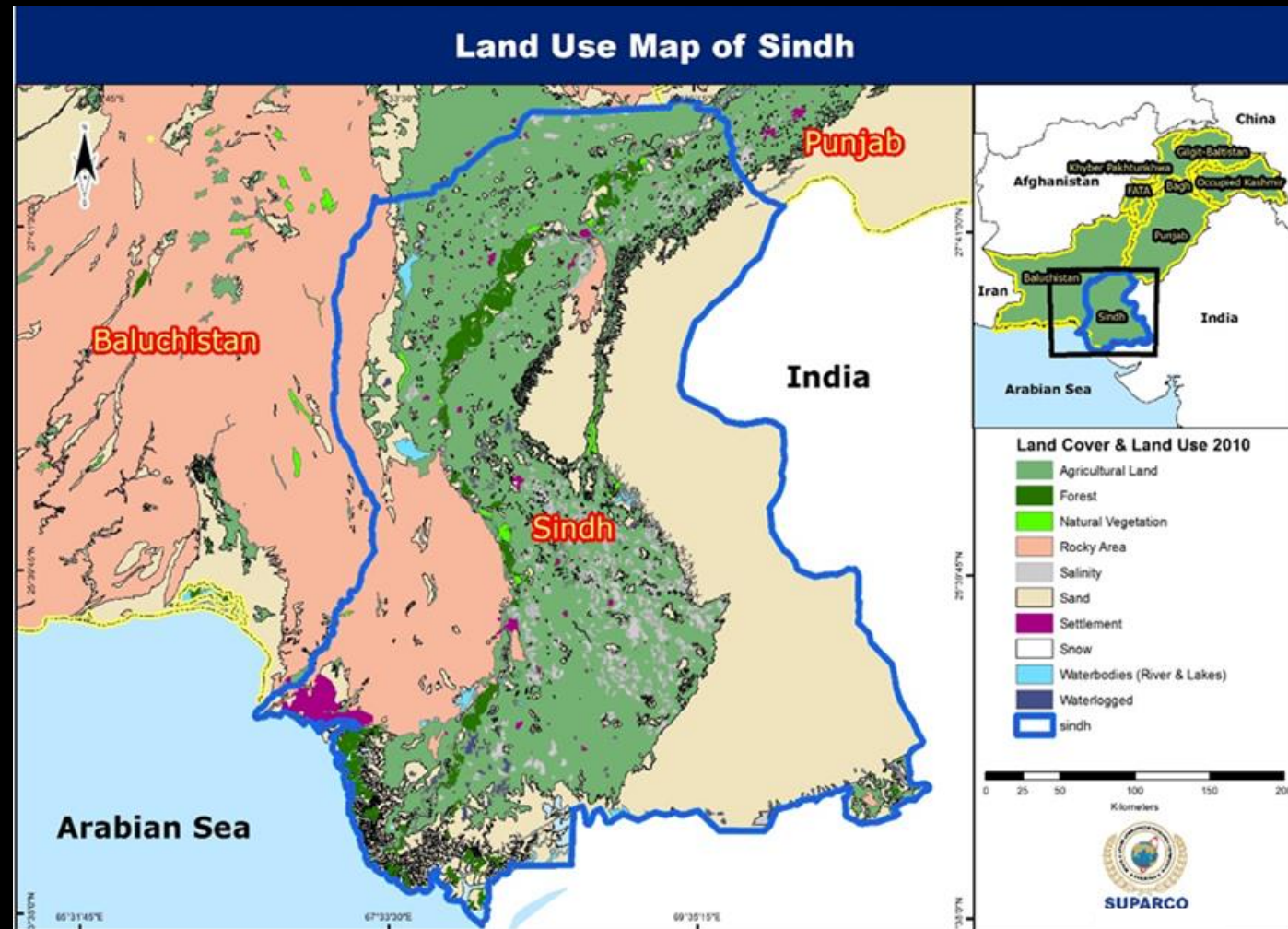
Meteorology

- Numerical weather prediction (NWP) models to improve forecast
- Early warning of droughts
- Climate change study

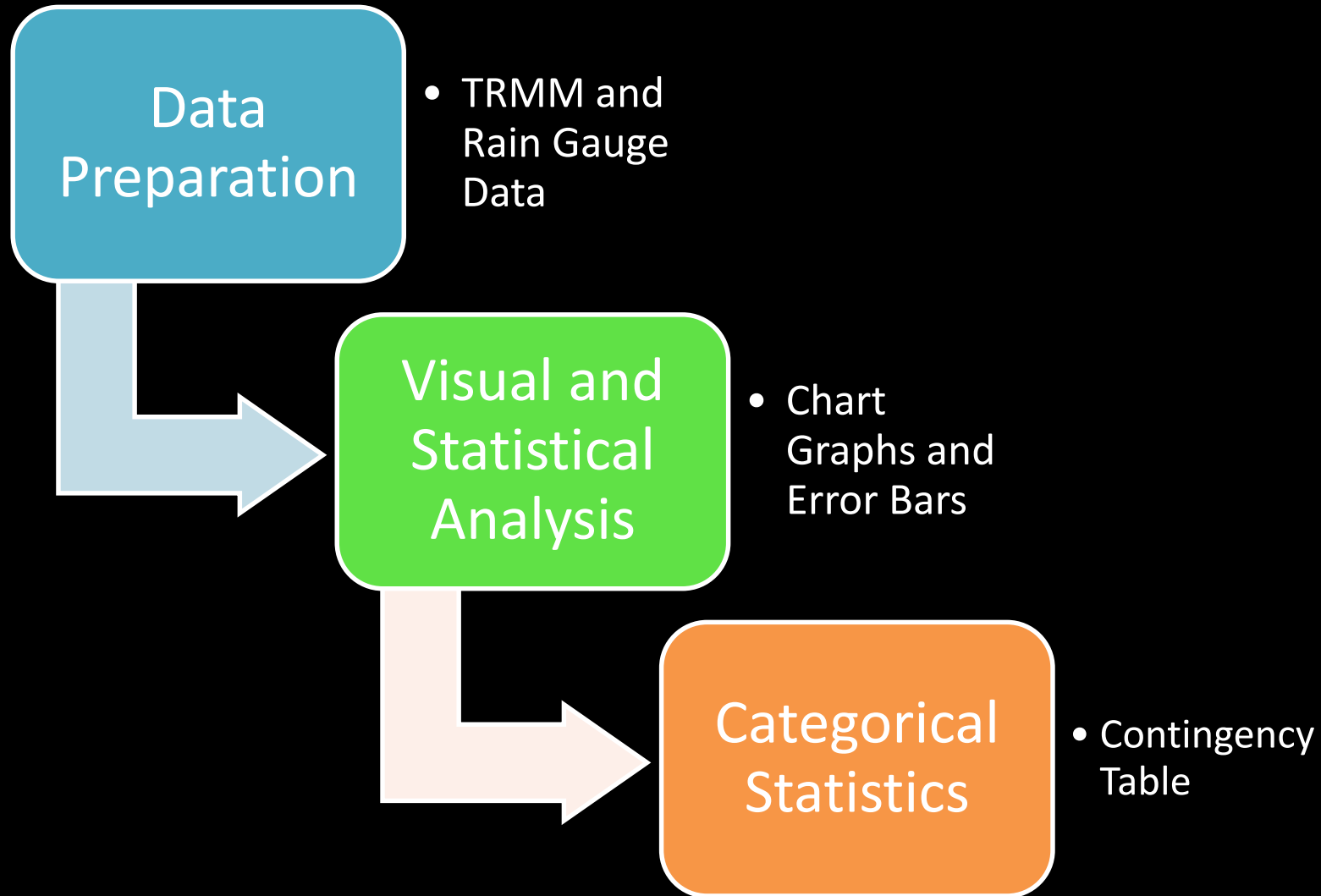


Study Area

- Lower Indus Plain Subtropical
- Average temperature ranges from 46 °C to 2 °C
- Annual rainfall averages 23 mm
- Study Period: 2001 - 2010



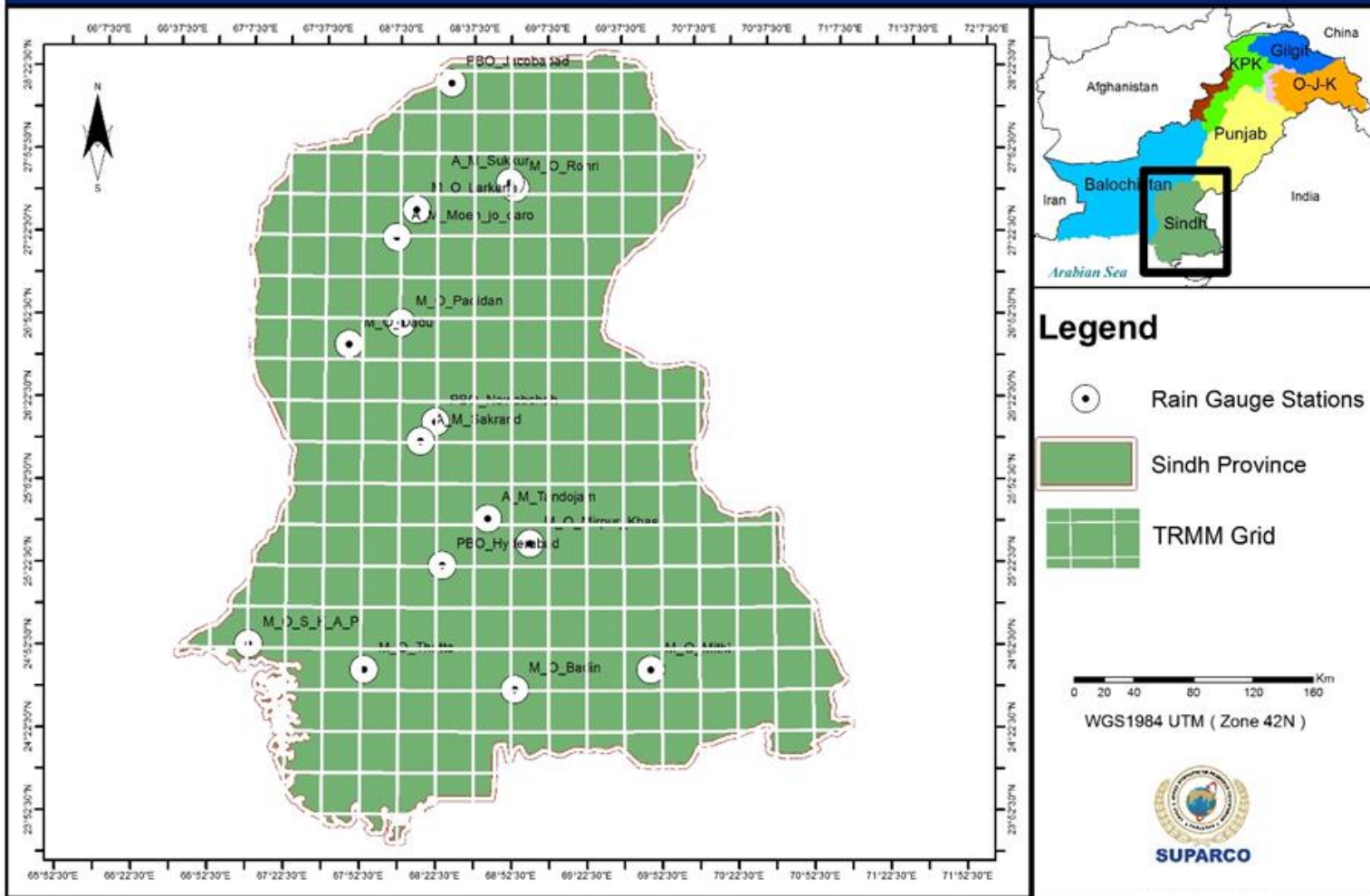
Methodology



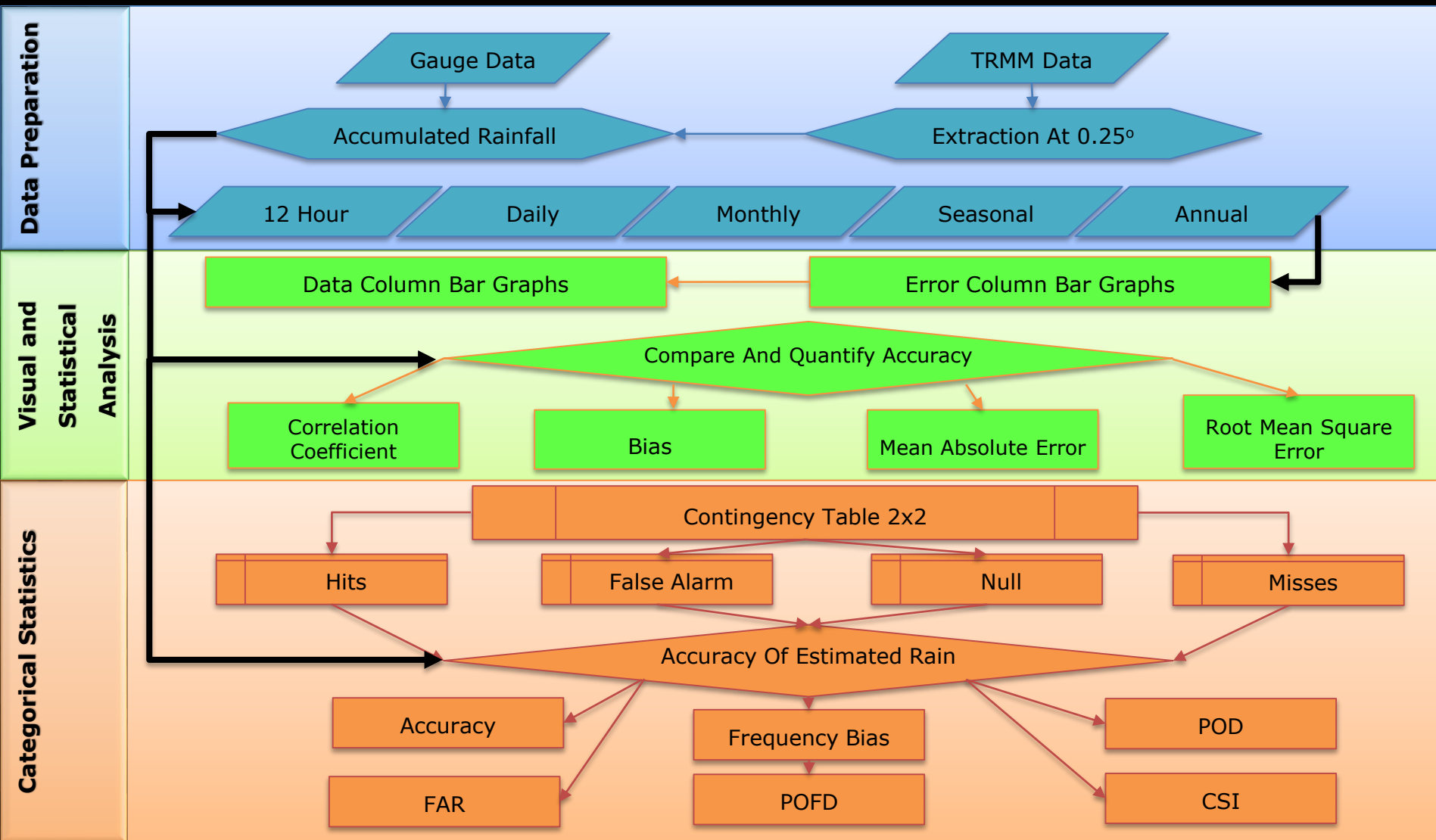
Methodology



TRMM Grid and Rain Gauge Stations



Methodology



Methodology



Contingency table

		OBSERVED VALUES RAIN GUAGE DATA		TOTAL
		YES	NO	
Predicted VALUES From TRMM	YES	Hit	False Alarm	TOTAL
	NO	Missed	Null	TOTAL
TOTAL		TOTAL	TOTAL	NUMBER OF SAMPLES

- Hit = the event occurred between the limits of prediction
- Miss = the event occurred outside the limits of prediction
- False Alarm = the event occurred less than the limits of prediction or does not occur
- Null = event estimated not to occur, and it occurred outside the limits

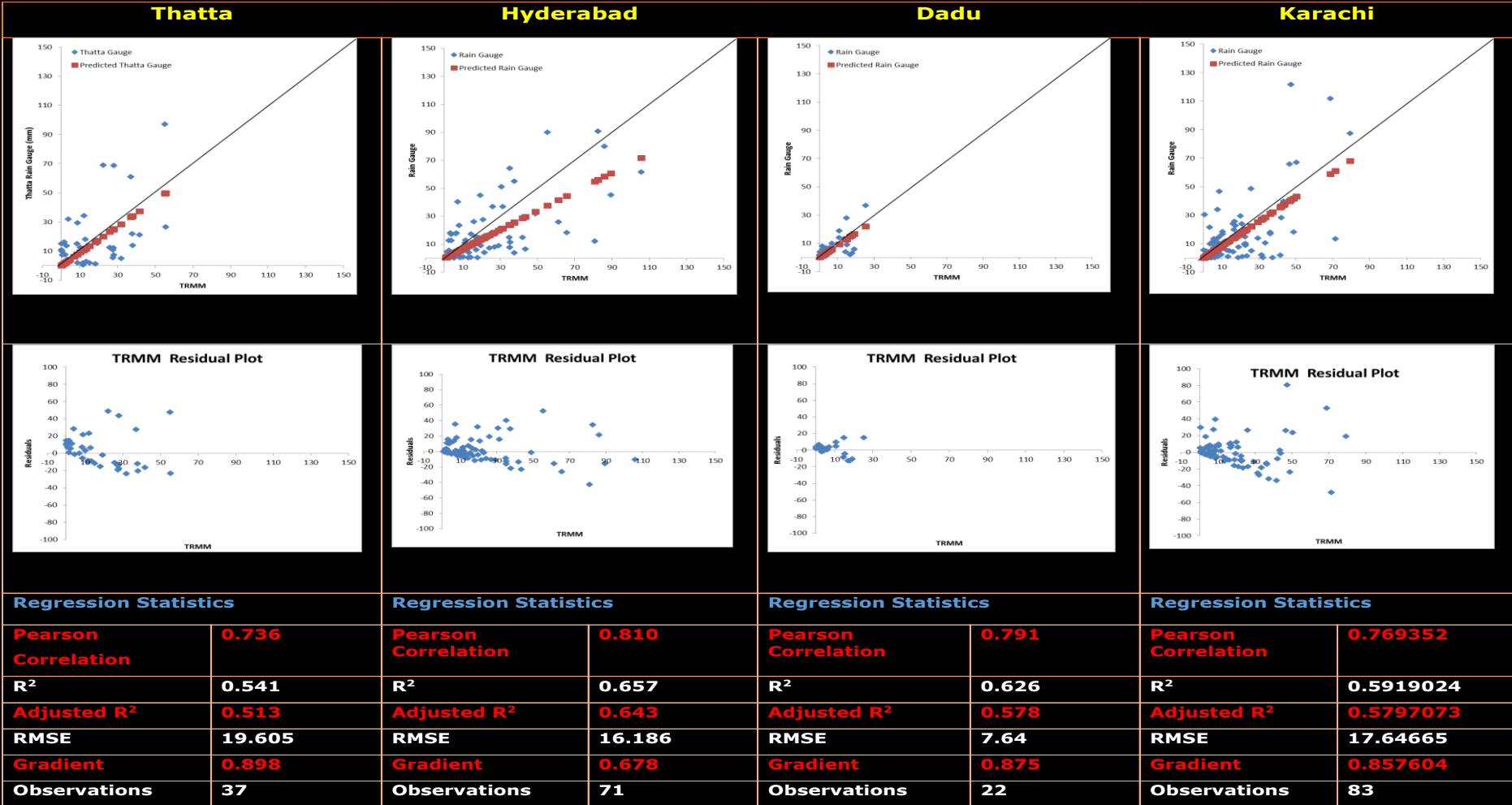
Results

- Person Correlation Co-efficient for all rain gauge stations
- Green values shows Higher values of R
- Red values shows Lower values of R

	Badin	Hyderabad	Karachi	Larkana	Mohenjo Daro	Mirpur Khas	Padedan	Rohari	Sukkur	Dadu
Badin	1									
Hyderabad	0.365	1								
Karachi	0.221	0.249	1							
Larkana	0.017	0.033	0.043	1						
Mohenjo Daro	0.086	0.095	0.102	0.289	1					
Mirpur Khas	0.451	0.37	0.15	0.04	0.115	1				
Padedan	0.062	0.137	0.29	0.161	0.381	0.08	1			
Rohari	0.084	0.067	0.112	0.279	0.294	0.084	0.237	1		
Sukkur	0.023	0.127	0.115	0.38	0.318	0.061	0.209	0.573	1	
Dadu	0.078	0.069	0.181	0.178	0.219	0.06	0.155	0.236	0.209	1

Results

12 hour Regression Statistics



Results

Statistical Analysis of Sensor monthly accumulated rainfall and Rain gauge measurements

Stations	Statistical analysis								Categorical statistics							
MONTHLY	Rain Gauge Measurements		TRMM Measurements		Cor.	Data Errors										
	Max	Min	Max	Min		BIAS	MAE	RMSE	Threshold		Accu.	FB	POD	FAR	POFD	CSI
	(mm)	(mm)	(mm)	(mm)		(mm)	(mm)	(mm)	(%)	(mm)						
Badin	307.7	0.3	408.2	0.094	0.92	-1.63	7.605	17.26	10	5	0.792	0.792	0.792	0	0	0.792
Hyderabad	220.2	0.2	214.1	0.382	0.849	-5.05	9.119	23.88	10	5	0.758	0.773	0.765	0.011	1	0.758
Karachi	272.7	0.2	272.7	0.089	0.93	-5.84	7.723	16.84	10	5	0.775	0.775	0.775	0	0	0.775
Larkana	217.4	0.4	96.06	0.017	0.777	-2.13	8.569	20.57	10	5	0.758	0.773	0.765	0.011	1	0.758
Mohenjo-daro	117.5	0.4	72.75	0.107	0.711	-2.4	6.365	13.47	10	5	0.8	0.8	0.8	0	0	0.8
Mirpurkhas	229.1	0.4	337.8	0.006	0.883	7.719	12.11	19.22	10	5	0.483	1.198	0.716	0.402	1	0.483
Padeidan	116.3	0.2	110.5	0.429	0.827	-1.68	5.228	13.11	10	5	0.85	0.85	0.85	0	0	0.85
Rohari	99.3	0.4	79.03	0.395	0.792	-0.4	4.384	10.61	10	5	0.875	0.875	0.875	0	0	0.875
Sukkur	130	0.4	54.48	0.423	0.656	-2.86	6.626	18.42	10	5	0.817	0.832	0.824	0.01	1	0.817
Dadu	307.7	0.3	408.2	0.094	0.924	-1.63	7.605	32.32	10	5	0.792	0.792	0.792	0	0	0.792
Thatta	220.2	0.2	214.1	0.382	0.849	-5.05	9.119	17.26	10	5	0.758	0.773	0.765	0.011	1	0.758

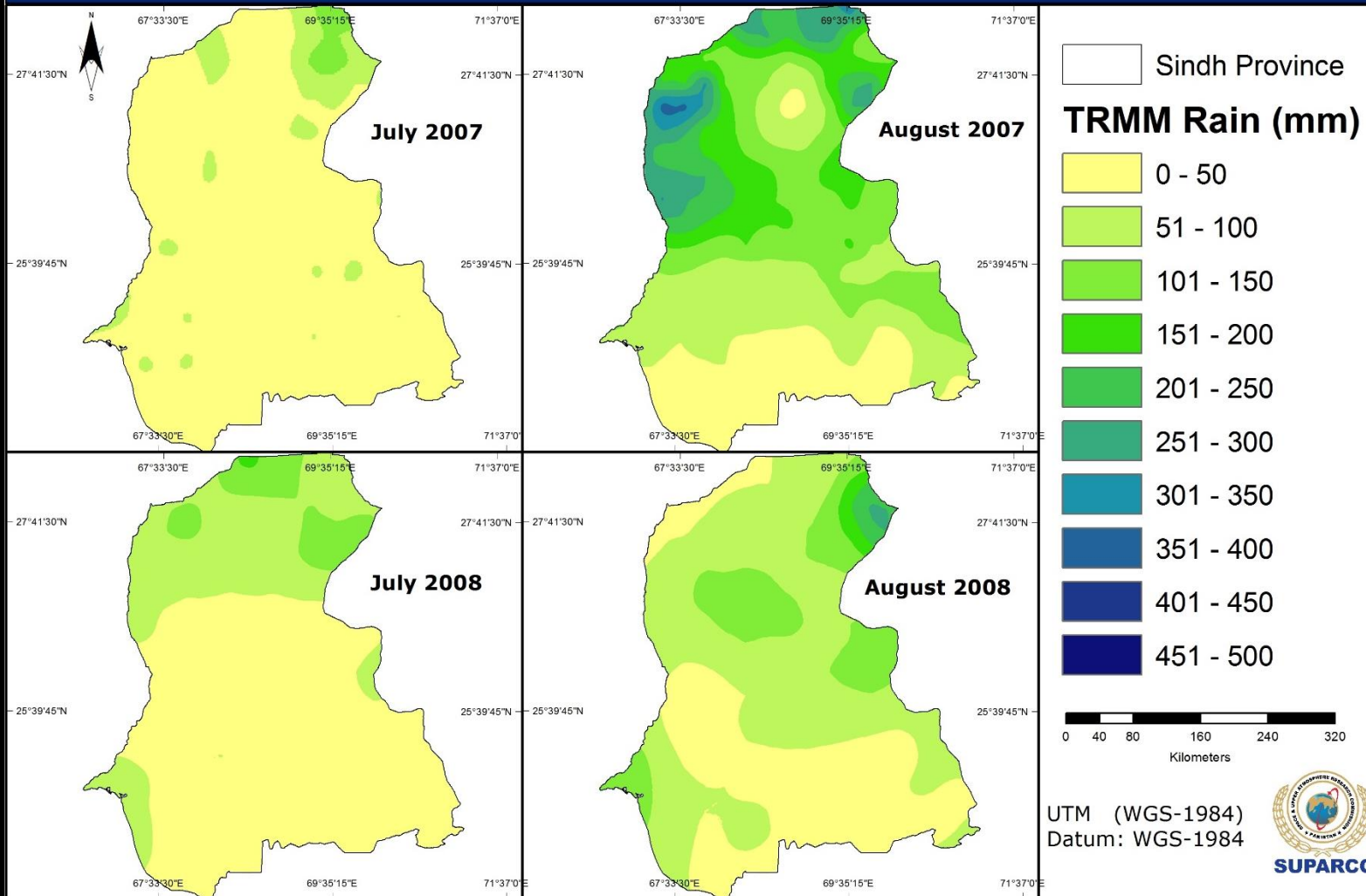
Results

- Statistics shows that for all periods a close relationship exists between rain gauge and satellite derived rainfall
- The highest R^2 (0.657) with RMSE (16.18) and lowest R^2 (0.33) with RMSE (12.43) exists for Hyderabad and Larkana meteorological stations respectively
- Eight out of eleven meteorological stations have correlation coefficient value greater than 0.7 (stronger correlation), while rest of them lie between 0.6 and 0.7 except Larkana with 0.58 (weaker correlation)
- The regression line gradient lies between 0.6 and 1.18. The regression line was adjusted for 3 standard deviation i.e., at 99% confidence interval for which adjusted R^2 ranges from 0.31 to 0.64
- The residual plots show the rainfall events are random, following the normal curve and independent of each other events

Results



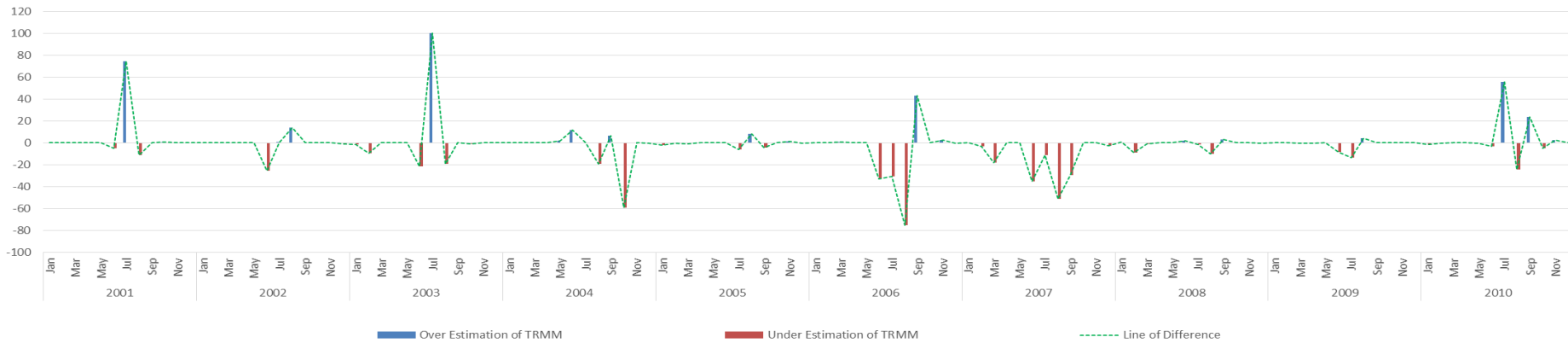
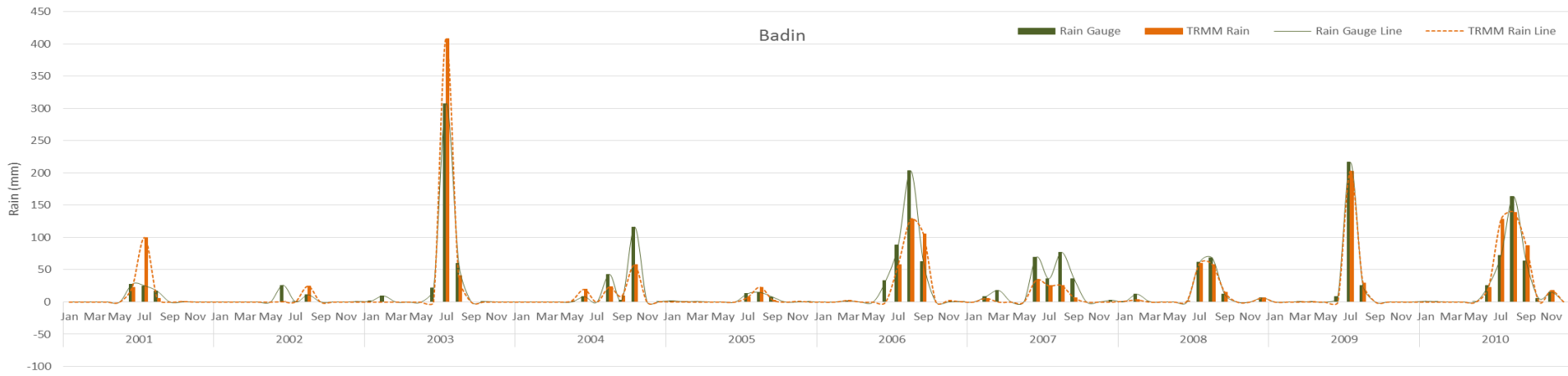
Interpolated TRMM Rainfall for July and August 2007-08



Results



Accumulative Monthly rainfall from rain gauge and TRMM comparison for Badin station





Conclusion

- Strong correlation exists between two datasets as correlation coefficient comes out to be 0.8 between field data and 12 hourly TRMM data. 0.5 (for daily TRMM Data values) and 0.9 (for monthly, seasonal and annual TRMM Data values)
- The highest values of correlation was in Post-monsoon and monsoon seasons while the lowest correlation values are found in summer.
- Larger deviations / underestimation in TRMM data are detected in locations which have more intense convection and localized rainfall and are prone to intense weather like cyclones and heavy rainfall during monsoon. Examples of such areas may include coastal regions / South of Lower Indus Plain
- It can be concluded that TRMM, with its provision of data at 0.25° spatial resolution, may be used for estimating the rainfall in the Province Sindh.

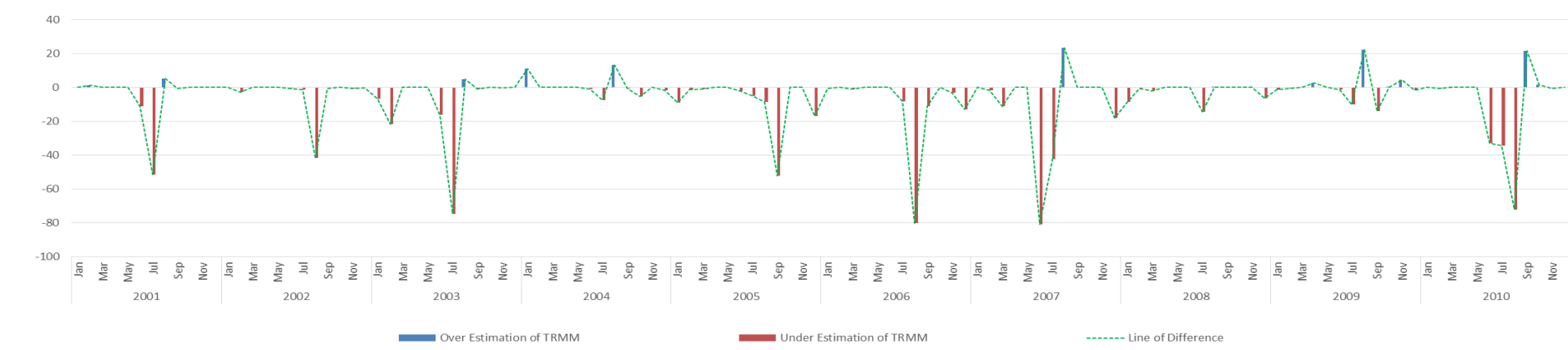
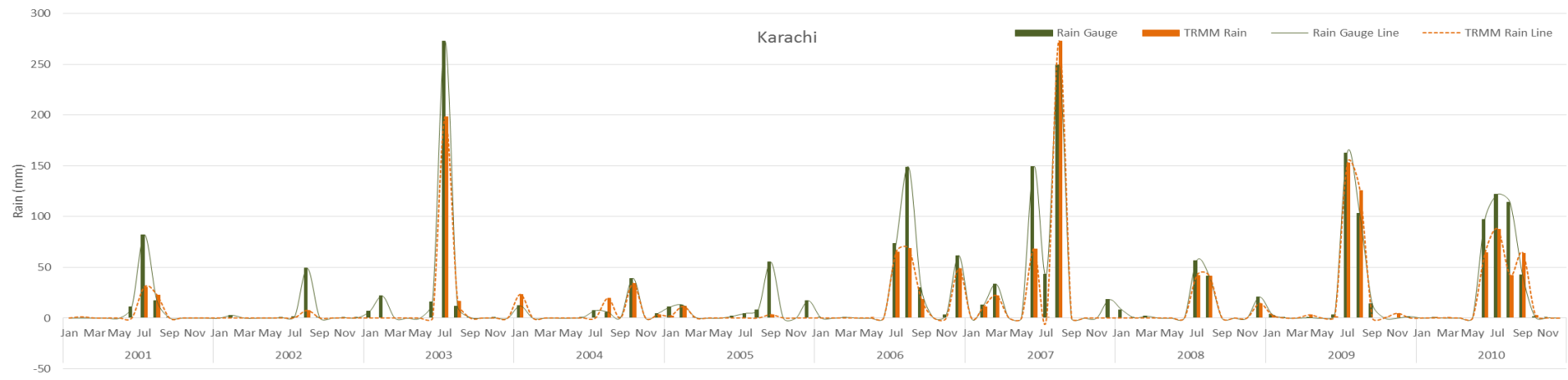


Thank You

Results



Accumulative Monthly rainfall from rain gauge and TRMM comparison for Karachi station



Results

Met. Stations	Half day (12 hours)					Daily				
	Max	Std Dev	Average	Missing Values	%age	Max	Std Dev	Mean	Missing Values	%age
Badin	92.40	3.07	0.29	0.00	0.00	118.90	4.76	0.58	0.00	0.00
Hyderabad	106.00	3.40	0.31	60.00	0.82	170.00	5.58	0.62	30.00	0.82
Karachi	121.60	3.44	0.32	0.00	0.00	130.30	5.32	0.63	0.00	0.00
Larkana	152.00	2.76	0.17	62.00	0.85	165.50	4.33	0.33	31.00	0.85
Mohen-jo-daro	75.00	1.81	0.14	0.00	0.00	75.00	2.74	0.28	0.00	0.00
Mirpur Khas	95.00	3.23	0.32	2372.00	32.48	95.00	4.76	0.63	1186.00	32.46
Padedan	59.40	1.85	0.16	0.00	0.00	59.40	2.87	0.32	0.00	0.00
Rohari	52.70	1.45	0.12	0.00	0.00	66.70	2.25	0.23	0.00	0.00
Sukkur	51.00	1.75	0.13	6.00	0.08	61.00	2.71	0.25	3.00	0.08
Thatta	97.20	3.20	0.29	1946.00	26.64	115.20	5.26	0.59	973.00	26.63
Dadu	35.00	1.61	0.18	2364.00	32.37	70.00	3.22	0.35	1182.00	32.35
			Monthly					Yearly		
Badin	307.70	44.83	17.66	0.00	0.00	400.60	131.66	211.87	0.00	0.00
Hyderabad	220.20	41.90	18.75	1.00	0.83	526.40	145.87	223.07	0.00	0.00
Karachi	272.70	45.49	19.18	0.00	0.00	506.20	146.16	230.11	0.00	0.00
Larkana	217.40	31.35	10.05	0.00	0.00	259.40	88.79	120.58	0.00	0.00
Mohen-jo-daro	117.50	19.01	8.61	0.00	0.00	326.60	84.09	103.28	0.00	0.00
Mirpur Khas	229.10	40.44	19.24	39.00	32.50	530.80	147.92	222.59	3.00	30.00
Padedan	725.60	144.41	69.10	0.00	0.00	238.70	84.90	116.44	0.00	0.00
Rohari	99.30	17.24	7.03	0.00	0.00	173.10	45.03	84.33	0.00	0.00
Sukkur	130.00	22.58	7.74	0.00	0.00	291.10	80.24	92.83	0.00	0.00
Thatta	181.10	39.46	17.84	32.00	26.67	415.70	132.87	196.29	2.00	20.00
Dadu	86.60	20.31	10.55	38.00	31.67	272.00	87.66	123.63	3.00	30.00

Stations	Statistical analysis								Categorical statistics							
Daily	Mean Surface Rainfall		Mean TRMM Rainfall		Data Errors				2x2 Table Statistics							
	Max	Min	Max	Min	Cor.	BIAS	MAE	RMSE	Threshold		Accu.	FB	POD	FAR	POFD	CSI
	mm	mm	mm	mm	mm	mm	mm	mm	(%)	mm						
Badin	292.3	0.094	118.9	0.3	0.525	-0.05	0.743	4.05	10	2.5	0.961	0.993	0.977	0.016	1	0.961
Hyderabad	107.8	0.382	193	0.1	0.365	-0.17	0.81	5.96	10	2.5	0.964	0.998	0.981	0.018	1	0.964
Karachi	134.7	0.089	130.3	0.2	0.49	-0.19	0.649	4.64	10	2.5	0.97	0.998	0.983	0.014	1	0.97
Larkana	75.02	0.006	165.5	0.3	0.264	-0.07	0.499	4.43	10	2.5	0.965	0.984	0.974	0.01	1	0.965
Mohenjo-daro	37.02	0.107	75	0.4	0.329	-0.08	0.374	2.59	10	2.5	0.971	0.993	0.982	0.011	1	0.971
Mirpurkhas	104	0.006	95	0.1	0.39	0.166	0.984	4.39	10	2.5	0.965	0.976	0.962	0.014	0.028	0.948
Padeidan	39.06	0.289	59.4	0.2	0.395	-0.06	0.394	2.64	10	2.5	0.969	0.991	0.98	0.012	1	0.969
Rohari	56.04	0.036	66.7	0.4	0.332	-0.01	0.33	2.12	10	2.5	0.97	0.986	0.978	0.008	1	0.97
Sukkur	56.04	0.036	61	0.1	0.298	-0.04	0.364	3.19	10	2.5	0.969	0.983	0.976	0.007	0.867	0.969
Dadu	43.95	0.006	70	0.8	0.153	0.063	0.653	5.88	10	2.5	0.967	0.974	0.962	0.012	0.023	0.951
Thatta	108.6	0.006	192	0.1	0.406	-0.11	0.78	4.05	10	2.5	0.974	0.986	0.975	0.011	0.029	0.965

Statistical Analysis of Sensor dry Season accumulated rainfall and Rain gauge measurements

SUBARCO

Stations	Statistical analysis								Categorical statistics							
DRY	Rain Gauge Measurements		TRMM Measurements		Cor.	Data Errors										
	Max	Min	Max	Min		BIAS	MAE	RMSE	Threshold		Accu.	FB	POD	FAR	POFD	CSI
	(mm)	(mm)	(mm)	(mm)		(mm)	(mm)	(mm)	(%)	(mm)						
Badin	27.5	1.6	6.4	0.89	0.7	-4.9	4.99	6.8	10	10	0.7	0.7	0.7	0	0	0.7
Hyderabad	214.4	0.4	30.92	2.21	0.93	-40	40.74	27.2	10	10	0.5	0.5	0.5	0	0	0.5
Karachi	108.3	2	82.29	0.29	0.9	-11.5	13.99	14.4	10	10	0.4	0.4	0.4	0	0	0.4
Larkana	139.3	1	104.5	0.12	0.8	-19.1	20.74	32.4	10	10	0.6	0.6	0.6	0	0	0.6
Mohenjo-daro	127.3	1.5	69.82	1.04	0.84	-19.9	21.51	26.0	10	10	0.7	0.7	0.7	0	0	0.7
Mirpurkhas	33.3	0.8	47.26	0.51	0.6	-0.4	9.16	12.3	10	10	0.6	0.78	0.67	0.14	1	0.6
Padeidan	119.9	0.4	41.35	1.29	0.76	-13	15.71	26.2	10	10	0.7	0.7	0.7	0	0	0.7
Rohari	161.1	0.4	89.17	1.59	0.94	-5.4	10.53	18.4	10	10	0.9	0.9	0.9	0	0	0.9
Sukkur	146.2	1.3	89.17	1.59	0.95	-8.5	11.21	14.7	10	10	0.7	0.7	0.7	0	0	0.7
Dadu	27.5	1.6	6.4	0.89	0.7	-4.9	4.99	34.5	10	10	0.7	0.7	0.7	0	0	0.7
Thatta	214.4	0.4	30.92	2.21	0.93	-40.7	40.74	12.5	10	10	0.5	0.5	0.5	0	0	0.5

Statistical Analysis of Sensor monsoon Season accumulated rainfall and Rain gauge measurements

Stations	Statistical analysis								Categorical statistics							
Monsoon	Rain Gauge Measurements		TRMM Measurements		Cor.	Data Errors										
	Max	Min	Max	Min		BIAS	MAE	RMSE	Threshold		Accu.	FB	POD	FAR	POFD	CSI
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(%)	(mm)						
Badin	367.3	11.4	448.7	25.16	0.934	2.714	40.04	52.1	10	50	0.5	0.5	0.5	0	0	0.5
Hyderabad	455.4	0.8	355.4	8.481	0.91	-9.44	41.72	61.8	10	50	0.7	0.7	0.7	0	0	0.7
Karachi	292.2	13.8	278.5	3.237	0.949	-43.9	45.07	38.1	10	50	0.6	0.6	0.6	0	0	0.6
Larkana	219.8	0.4	139.3	1.333	0.876	-7.66	36.92	44.1	10	50	0.6	0.6	0.6	0	0	0.6
Mohenjo-daro	135.9	0.8	122.8	4.304	0.796	-8.23	17.81	31.9	10	50	0.9	0.9	0.9	0	0	0.9
Mirpurkhas	475.2	22.6	506.2	6.915	0.777	85.49	85.49	98.5	10	50	0.5	0.875	0.625	0.286	1	0.5
Padeidan	195.9	2.4	150.3	12.23	0.91	-13.3	22.5	31.8	10	50	0.8	0.8	0.8	0	0	0.8
Rohari	100.3	0.4	110.9	0.395	0.907	6.513	11.55	13.8	10	50	1	1	1	0	0	1
Sukkur	144	1.6	110.9	0.395	0.452	-4.61	37.15	54.0	10	50	0.7	0.7	0.7	0	0	0.7
Dadu	367.3	11.4	448.7	25.16	0.934	2.714	40.04	38.4	10	50	0.5	0.5	0.5	0	0	0.5
Thatta	455.4	0.8	355.4	8.481	0.91	-9.44	41.72	105.9	10	50	0.7	0.7	0.7	0	0	0.7

Statistical Analysis of Sensor annual accumulated rainfall and Rain gauge measurements

SUBARCO

Stations	Statistical analysis								Categorical statistics							
Annual	Rain Gauge Measurements		TRMM Measurements		Cor.	Data Errors										
	Max	Min	Max	Min		BIAS	MAE	RMSE	Threshold		Accu.	FB	POD	FAR	POFD	CSI
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(%)	(mm)						
Badin	400.6	38.2	448.7	25.69	0.893	-19.6	50.64	66.1	10	60	0.8	0.8	0.8	0	0	0.8
Hyderabad	526.4	11	356.1	8.862	0.905	-60.6	76.03	75.9	10	60	0.4	0.4	0.4	0	0	0.4
Karachi	506.2	55.2	375.2	7.877	0.951	-70.1	72.07	50.7	10	60	0.5	0.5	0.5	0	0	0.5
Larkana	259.4	12.4	205.7	21.23	0.717	-25.6	54.23	63.9	10	60	0.6	0.6	0.6	0	0	0.6
Mohenjo-daro	326.6	17.2	136.7	11.44	0.727	-28.8	40.62	64.5	10	60	0.9	0.9	0.9	0	0	0.9
Mirpurkhas	530.8	81.1	540.2	22.05	0.781	92.63	94.09	111.9	10	60	0.4	0.75	0.5	0.333	1	0.4
Padeidan	238.7	10.6	190.3	6.609	0.947	-20.1	27.83	30.4	10	60	0.9	0.9	0.9	0	0	0.9
Rohari	173.1	8.9	154.5	10.07	0.839	-4.76	22.13	27.4	10	60	1	1	1	0	0	1
Sukkur	291.1	9	154.5	10.07	0.64	-13.3	46.39	68.9	10	60	0.7	0.7	0.7	0	0	0.7
Thatta	415.7	70.1	338.6	11.69	0.578	8.205	87.42	99.0	10	60	0.5	0.875	0.625	0.286	1	0.5
Dadu	272	24	217.2	12.21	0.294	40.63	89.42	136.5	10	60	0.3	0.625	0.375	0.4	1	0.3