Assessing the impact of climate change for Mahanadi basin using SWAT model

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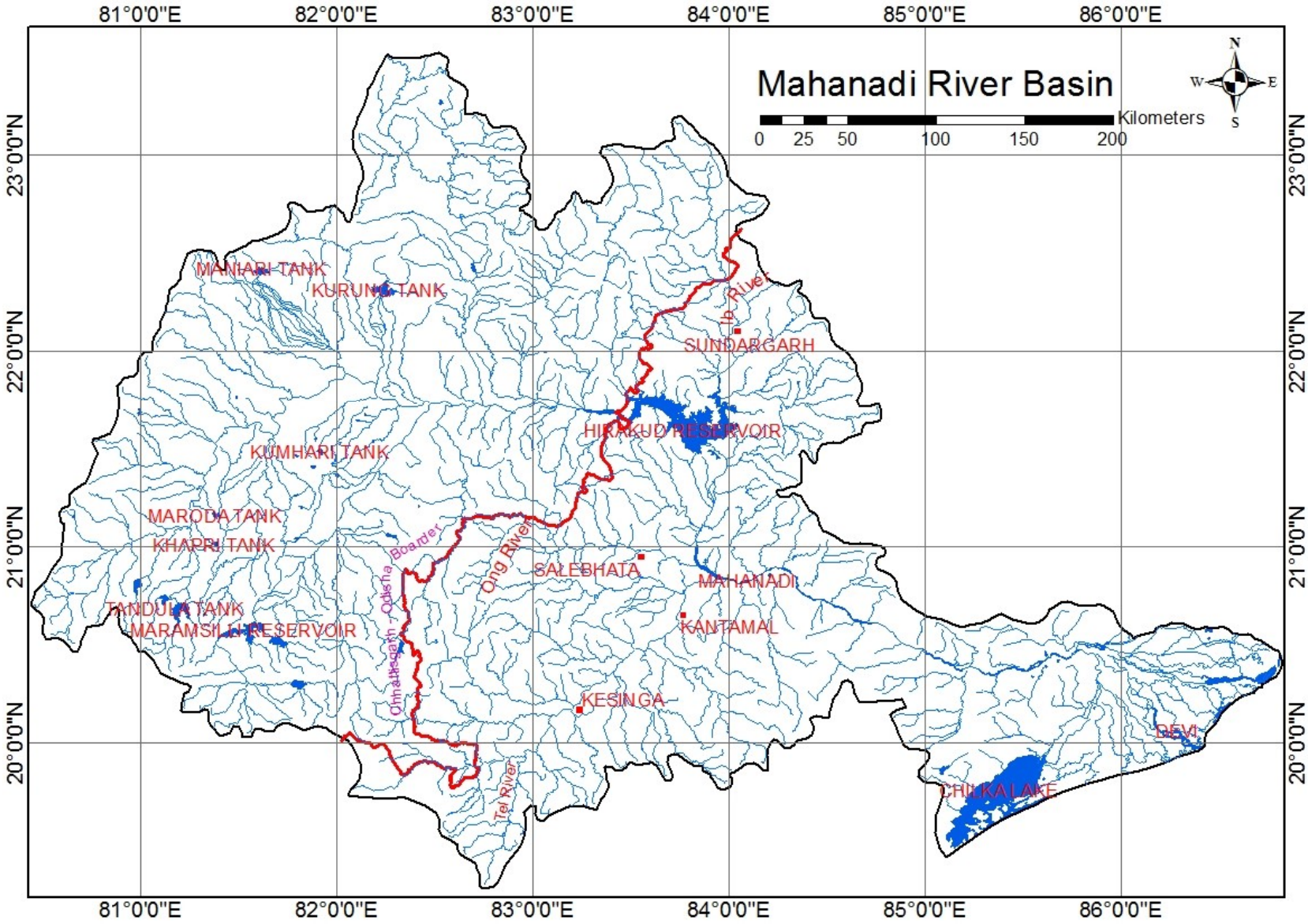
Objectives:

- Assessment of change in hydrometerological and hydrological data by employing statistical significance test.
- To downscale the GCMs output
- Hydrological assessment using SWAT model

Study area map



Data collected

S. No.	Gauaging site	Period	Years	Catchment area (km^2)
1	Salebhatta	1971-2009	39	4650
2	Sundergarh	1978-2009	32	5870
3	Kesinga	1978-2009	32	11,960
4	Kantamal	1971-2009	39	19,600

IMD gridded rainfall data (1^0 X 1^0) from 1901 to 2004

GCM Data

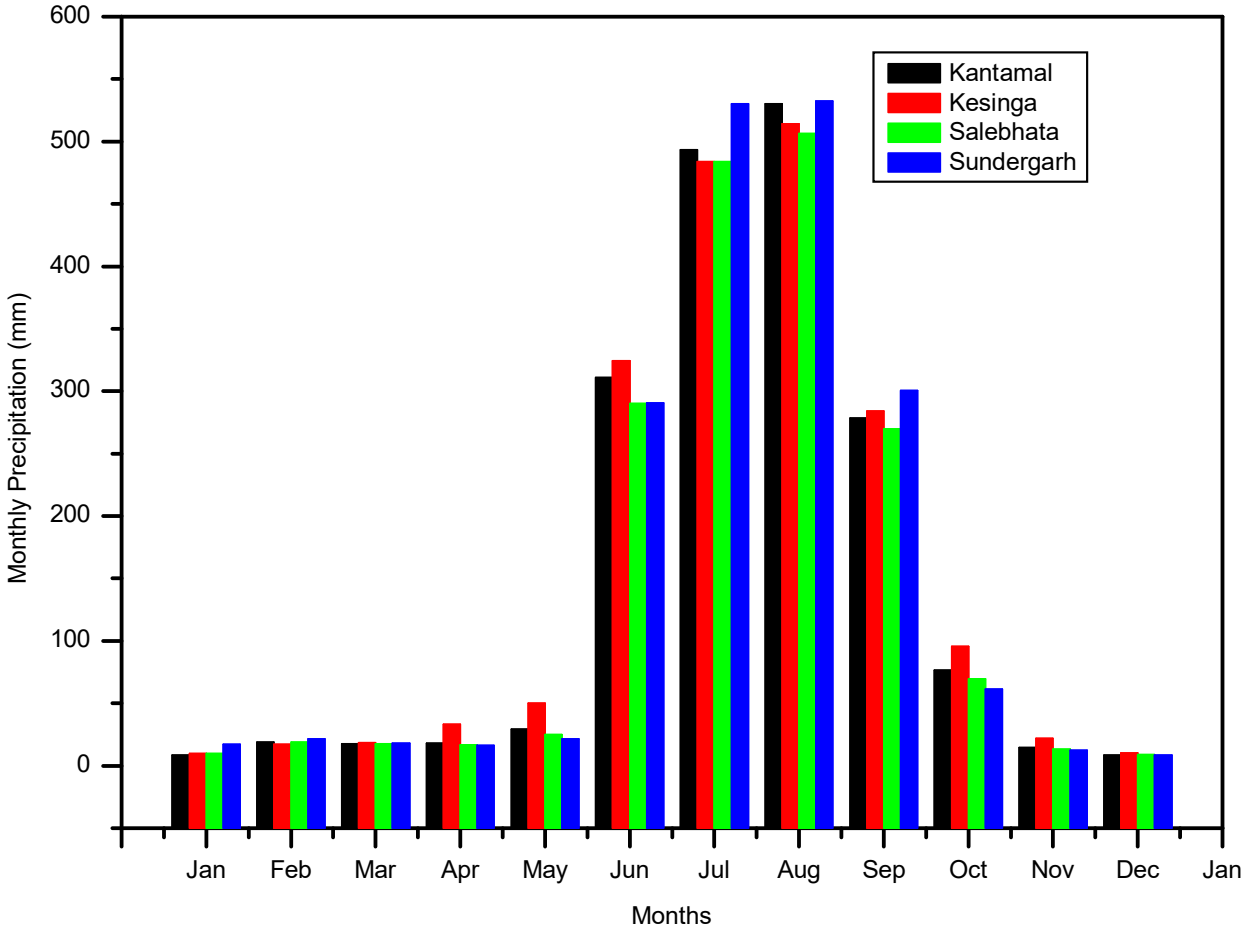
Environment Canada, Canadian Centre for Climate Modelling and Analysis, CanESM2, R1, R2, R3, R4, R5 (256 X 192)

- Historical data (1951 – 2005)
- Future projection : 2006 - 2100 (*eg.*, RCP 2.6, 4.5, 8.5 Scenario)

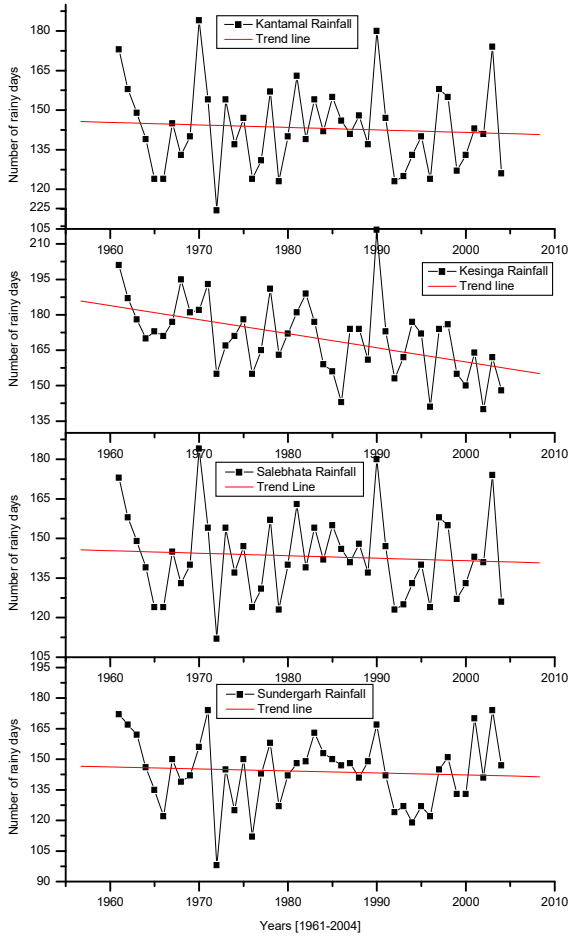
MK Sign Test Statistics for Discharge data

S. No.	Gauaging site	H	alpha	Z	Inference
1	Salebhatta	1	0.05	-3.989	Decreasing trend in the Pre-whitened series
2	Sundergarh	0	0.05	-0.2377	NO trend in the Pre-whitened series
3	Kesinga	1	0.05	35.79	Increasing trend in the Pre-whitened series
4	Kantamal	1	0.05	30.11	Increasing trend in the Pre-whitened series

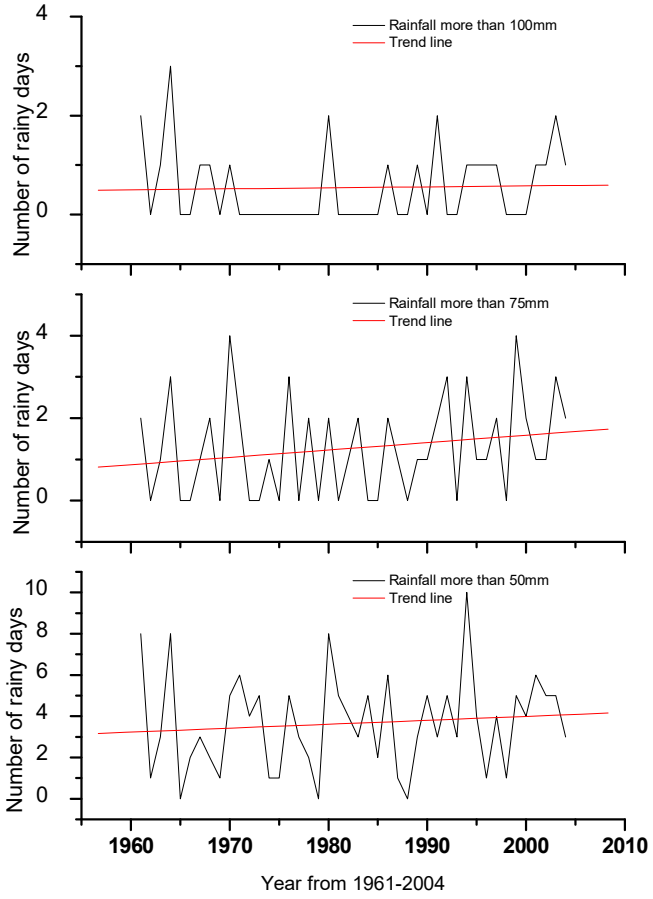
Monthly Total Precipitation [1961-2004]



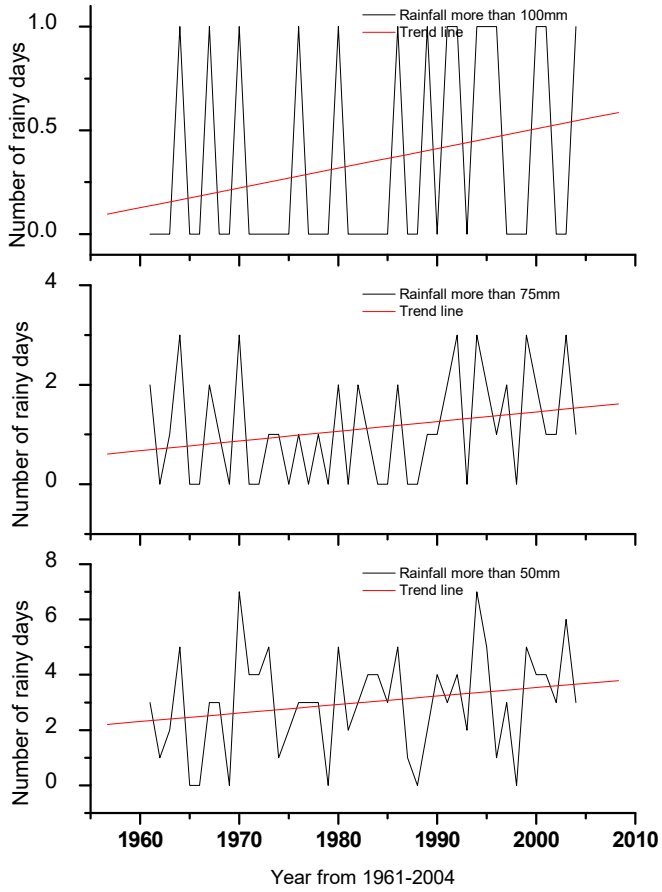
Plot showing number of rainy days for different sub-basin in Mahanadi river



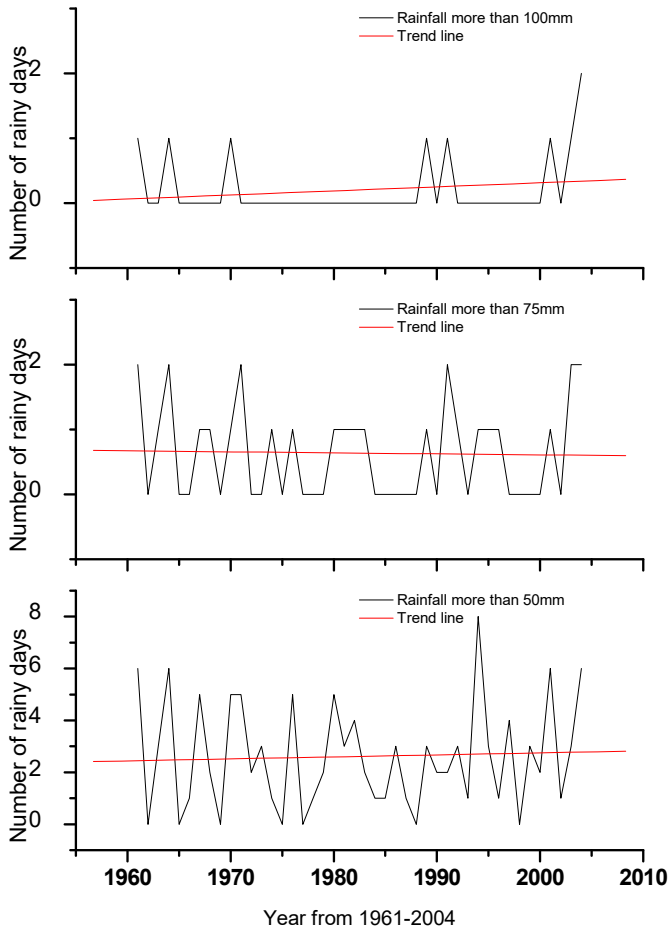
Plot showing number of rainy days for 1 day maximum rainfall for Kantamal subbasin in Mahanadi river



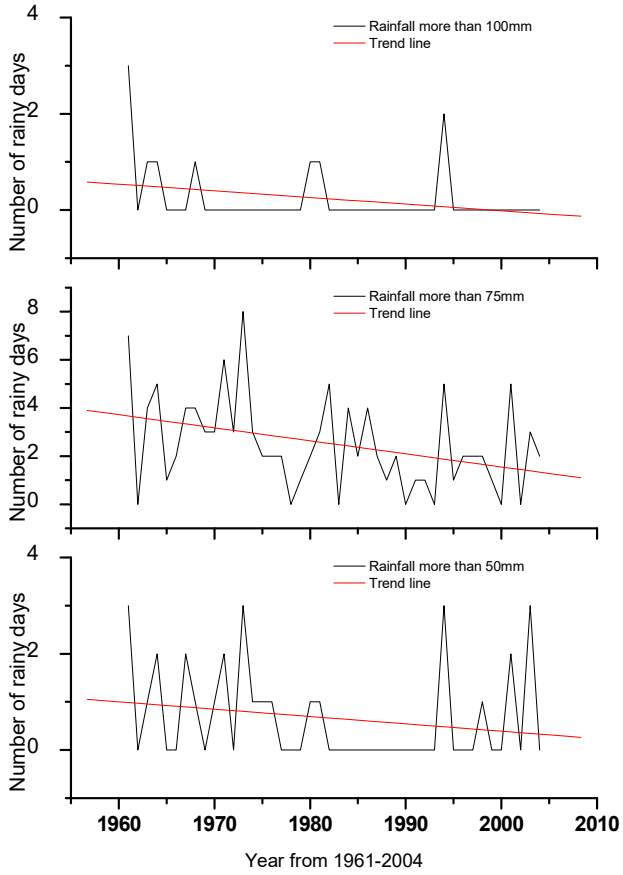
Plot showing number of rainy days for 1 day maximum rainfall for Kesinga sub – basin in Mahanadi river



Plot showing number of rainy days for 1 day maximum rainfall for Salebhata sub basin in Mahanadi river



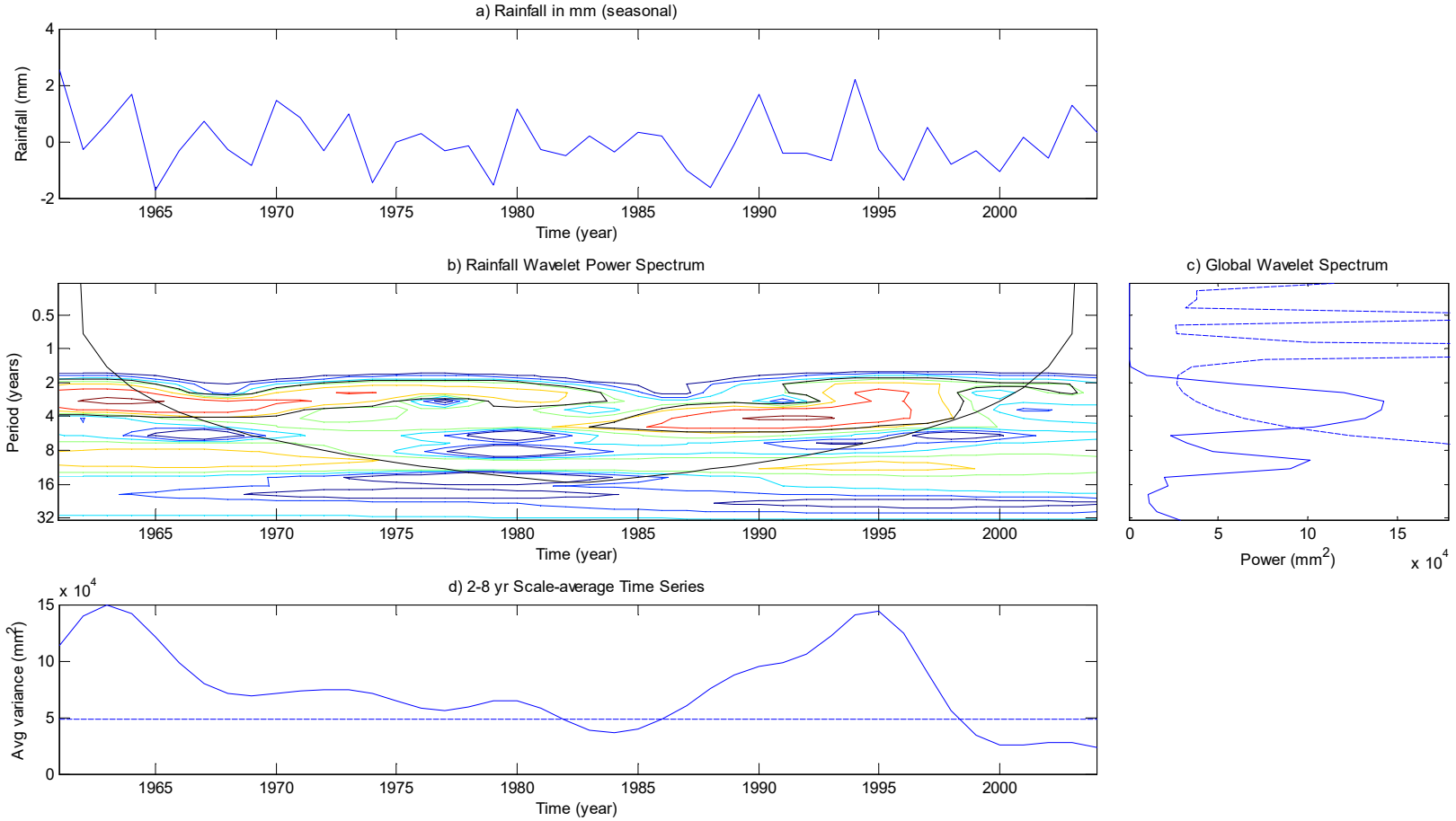
Plot showing number of rainy days 1 day maximum rainfall for Ib sub-basin in Mahanadi river



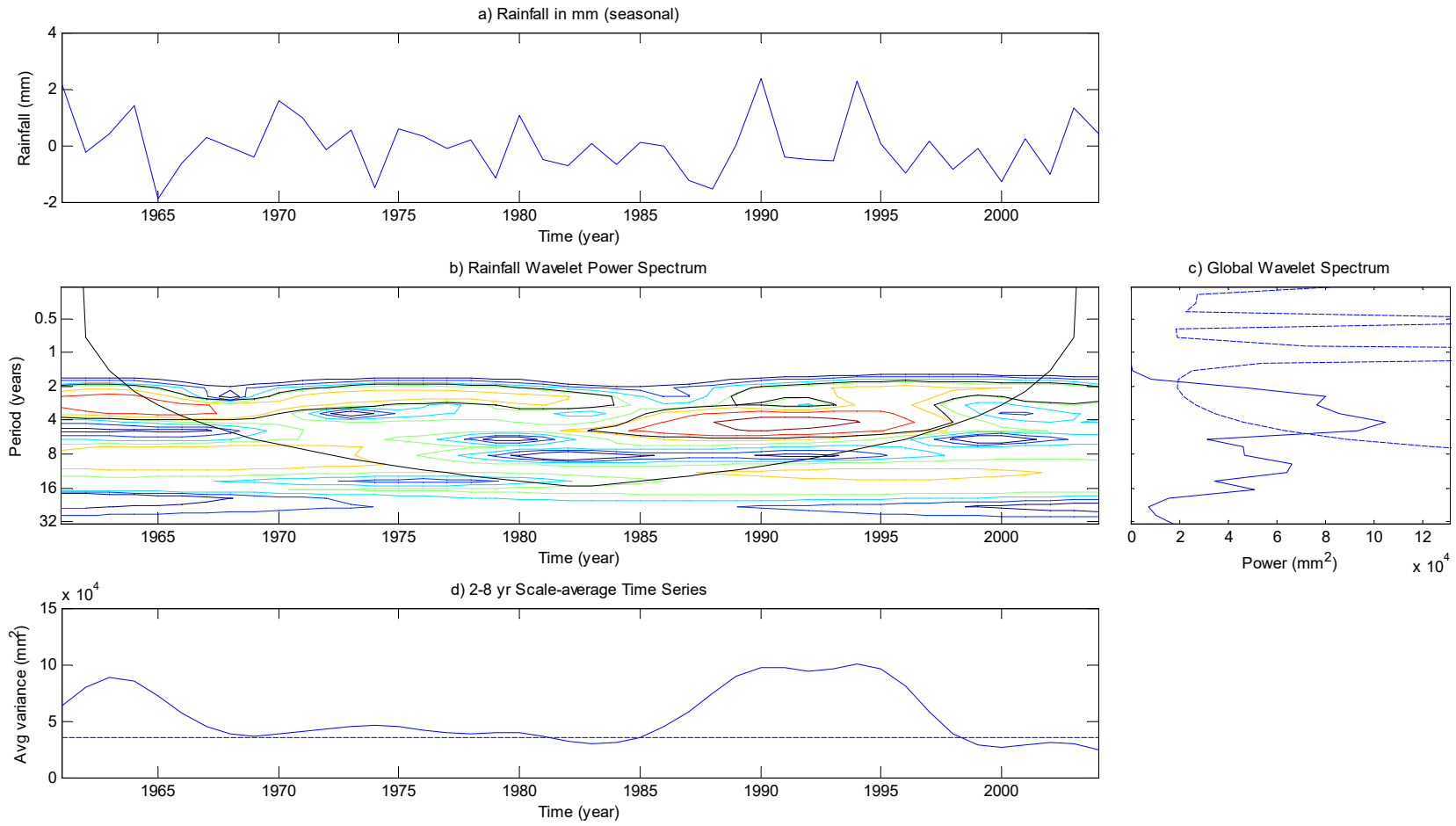
Regime Shift Detection Test

Wavelet analysis is becoming a common tool for analyzing localized variations of power within a time series. By decomposing a time series into time–frequency space, one is able to determine both the dominant modes of variability and how those modes vary in time.

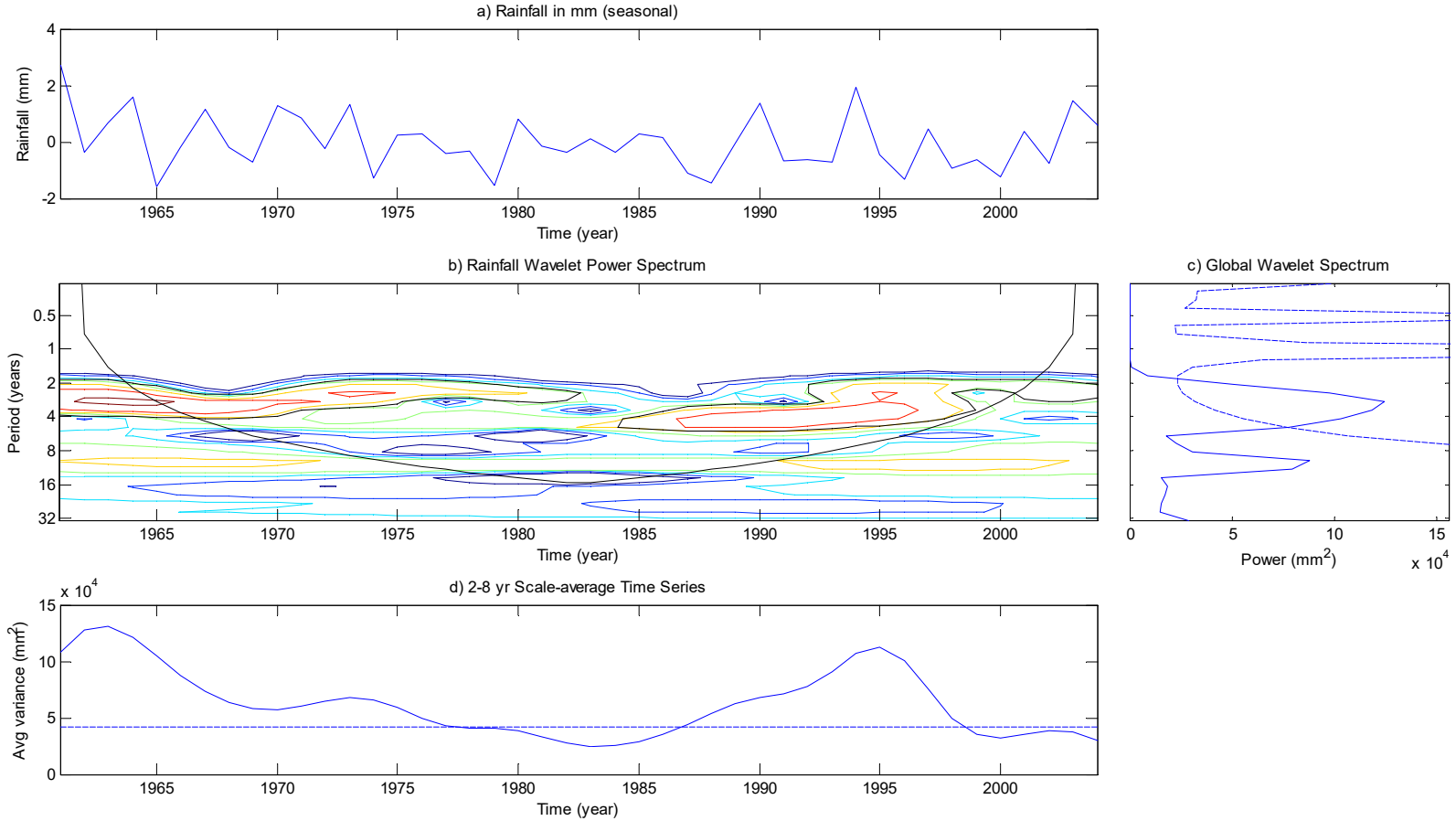
Kantamal Sub-basin



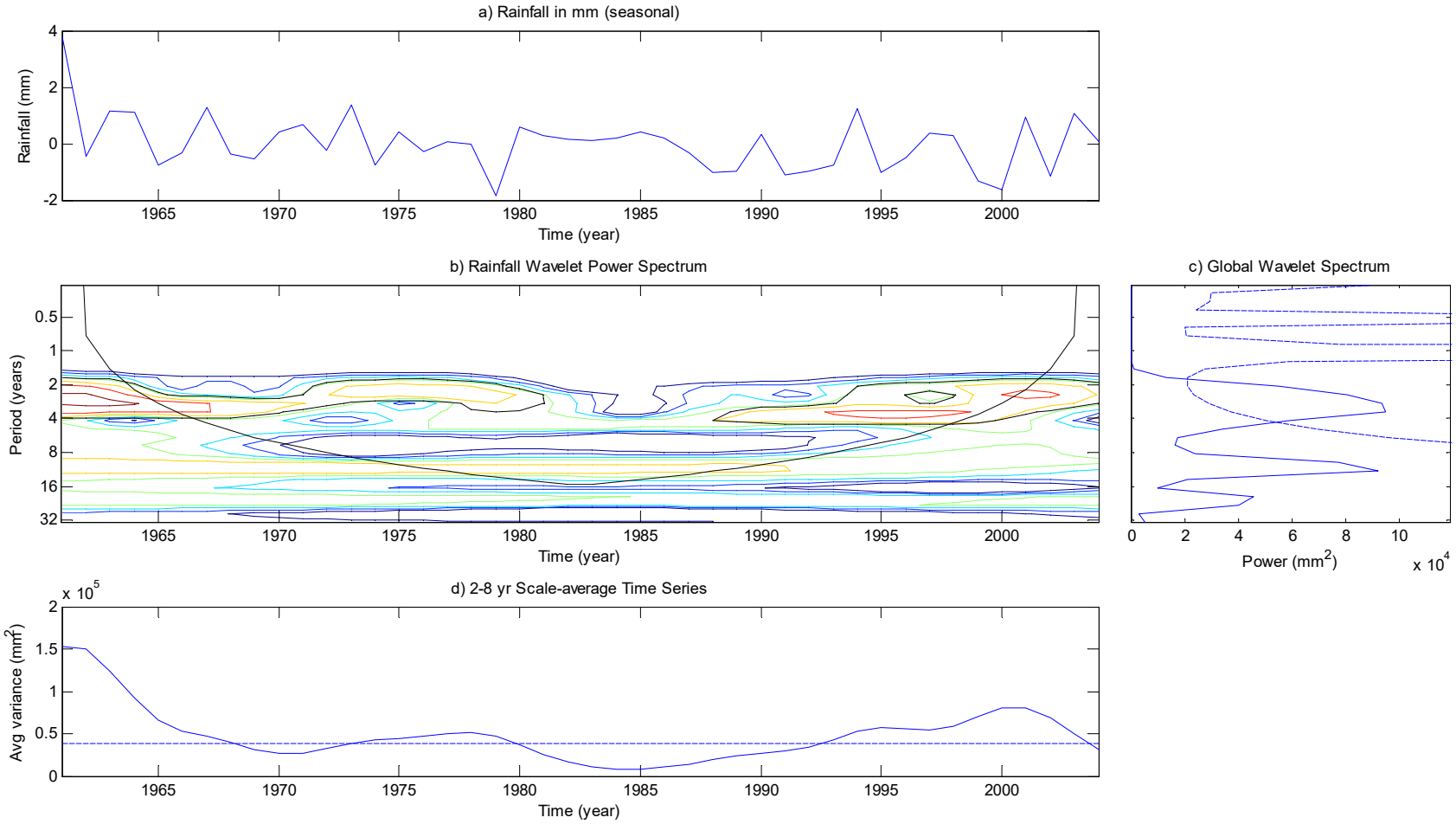
Kesinga Sub-basin



Salebhata Sub-basin



Ib Sub-basin


a) Rainfall in mm (seasonal)
Rainfall (mm)
4
2
0
-2
1965
1970
1975
1980
1985
1990
1995
2000
Time (year)
b) Rainfall Wavelet Power Spectrum
Period (years)
0.5
1
2
4
8
16
32
Time (year)
c) Global Wavelet Spectrum
0
2
4
6
8
10
Power (mm2)
x 10^4
d) 2-8 yr Scale-average Time Series
x 10^5
Avg variance (mm2)
2
1.5
1
0.5
0
Time (year)

Downscaling Precipitation

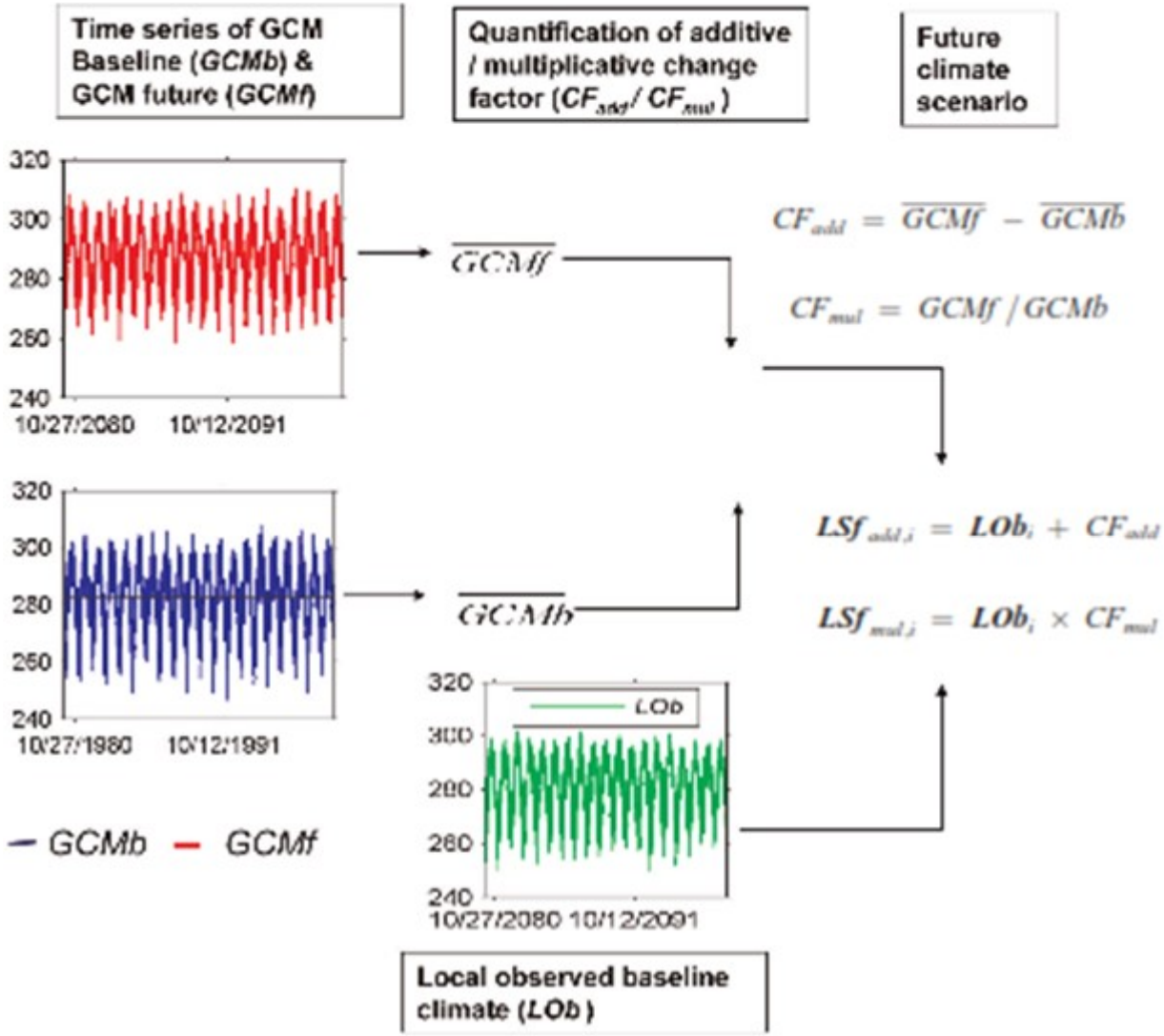
The area of typical GCM grid cells range between 10,000 km^2 and 90,000^2 km, but watershed area is less than GCM Grid area, there is difference/ mismatch in spatial scales.

To overcome mismatched spatial scale:

- (1) based on analogies with different climatic zones
- (2) Downscaling methodologies (statistical/dynamic).

There are three types of statistical downscaling, namely weather classification methods, weather generators, and transfer functions methods.

Change Factor Methodology



Anandhi, A., A. Frei, D. C. Pierson, E. M. Schneiderman, M. S. Zion, D. Lounsbury, and A. H. Matonse (2011), Examination of change factor methodologies for climate change impact assessment, Water Resour. Res., 47, W03501, doi:10.1029/2010WR009104.

Downscaling Precipitation

- **CanESM2_1960_2005_R1 & CanESM2_2006_2100_R1_RCP26**
- **CanESM2_1960_2005_R1 & CanESM2_2006_2100_R1_RCP45**
- **CanESM2_1960_2005_R1 & CanESM2_2006_2100_R1_RCP85**
- **CanESM2_1960_2005_R1 & CanESM2_2006_2100_R2_RCP26**
- **CanESM2_1960_2005_R1 & CanESM2_2006_2100_R2_RCP45**
- **CanESM2_1960_2005_R1 & CanESM2_2006_2100_R2_RCP85**
- **CanESM2_1960_2005_R1 & CanESM2_2006_2100_R3_RCP26**
- .
- .
- .
- .

- Total 75 projections are generated using CFM for each sub-basin)

Uncertainty analysis

- To establish confidence in the projected precipitation downscaled from GCM scenario outputs, it was important that the downscaled outputs represented the current state of the precipitation regimes reasonably well. In fact, the confidence on the reliability of the climate change anomalies computed from the scenarios run relied on the downscaled outputs' ability to represent the baseline Climate.

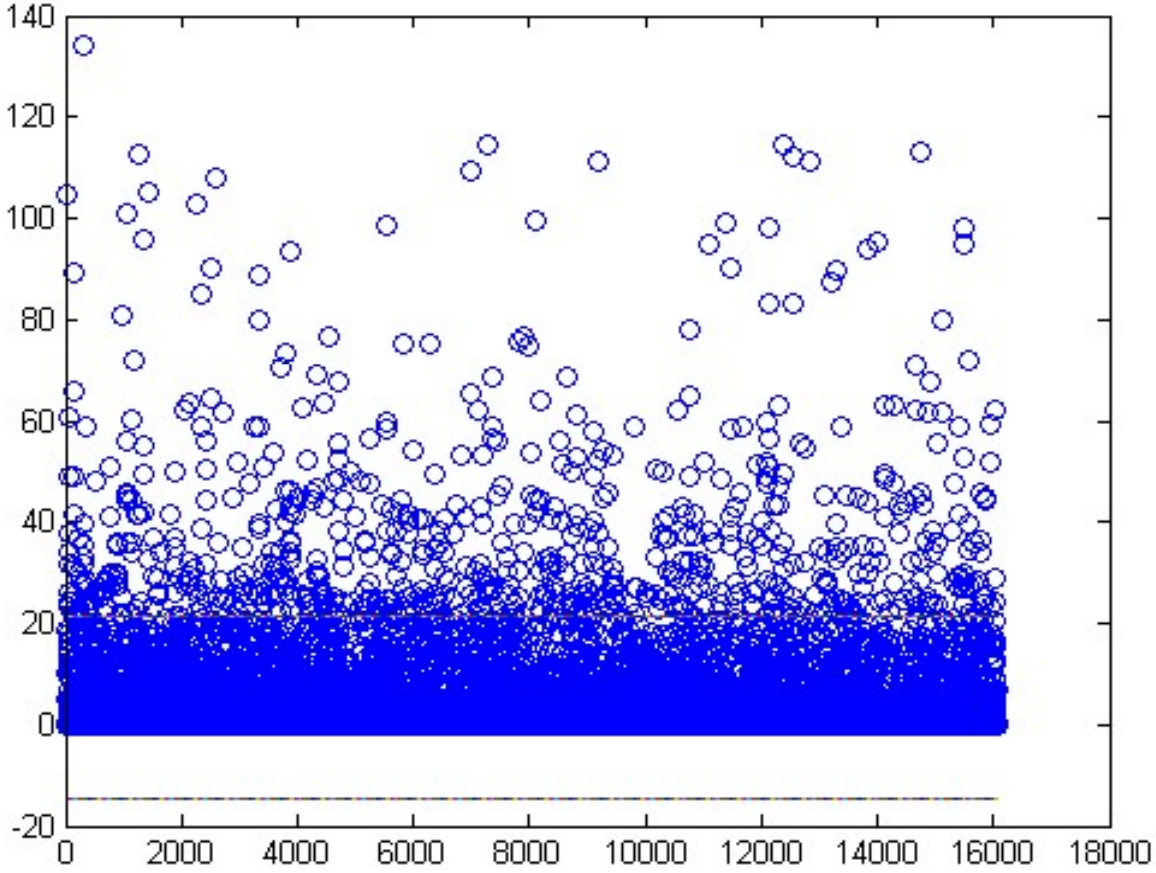
Non-parametric Uncertainty Test

- The Wilcoxon Signed Rank test (Wilcoxon, 1945) is one of the best nonparametric methods for conducting hypothesis tests (Conover, 1980) and widely used in uncertainty analysis of downscaled climate parameters provided with predictor scenarios of the GCMs (Dibike et al., 2008; Khan et al., 2006a,b).

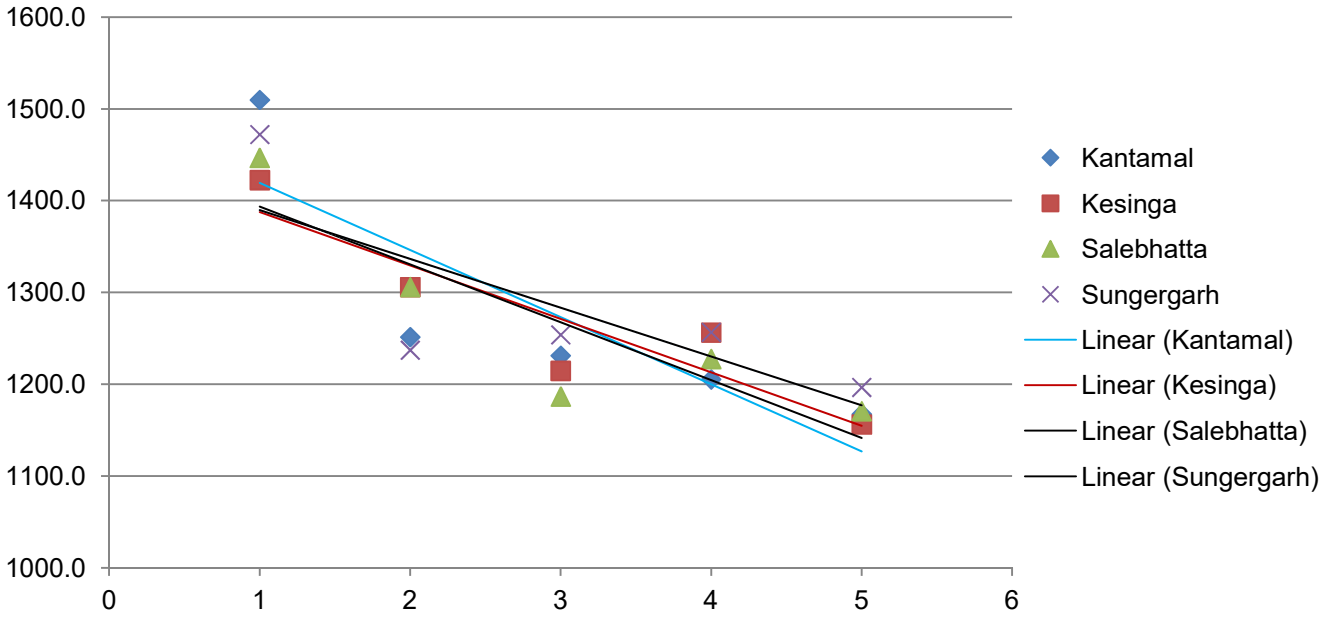
Uncertainty Test

- Analysis carried out using daily, monthly, seasonal and annual GCM downscaled precipitation data. If more than 20% data is outside the 95% confidence level, is rejected.
- Monthwise (Jan, Feb, Mar, …time series) uncertainty analysis is carried out to check the variation in projected future rainfall.

Plot showing data band

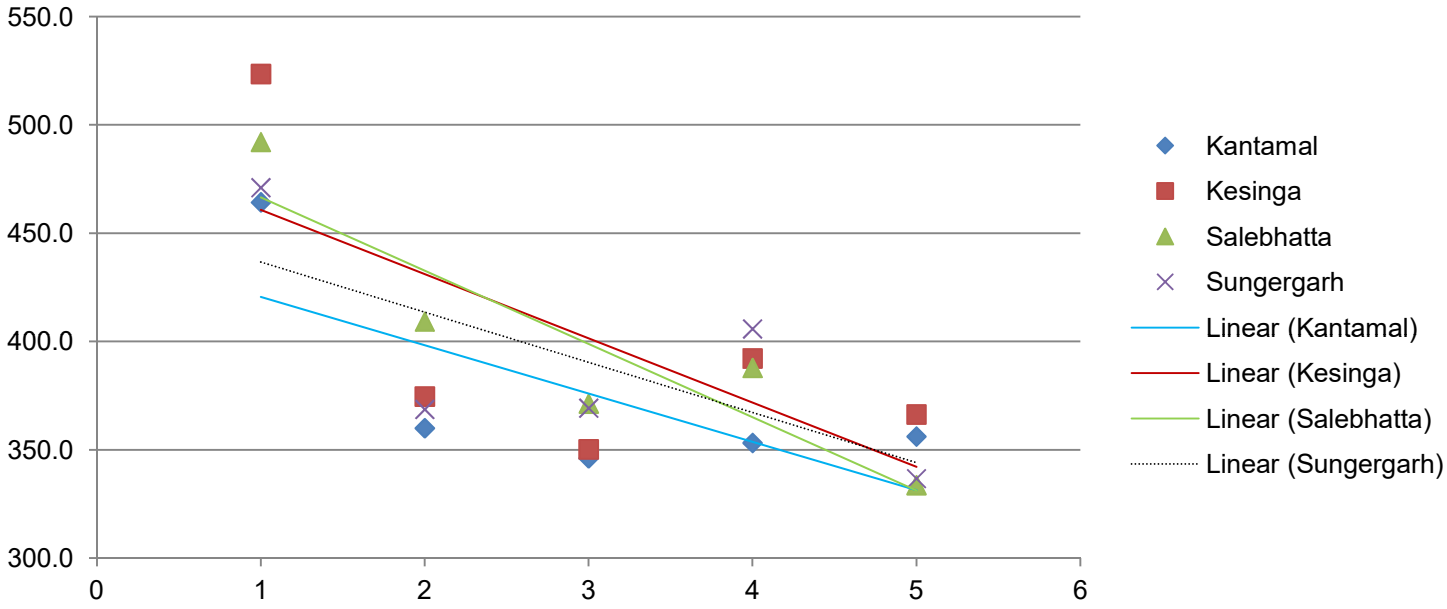


Decadal Rainfall variation



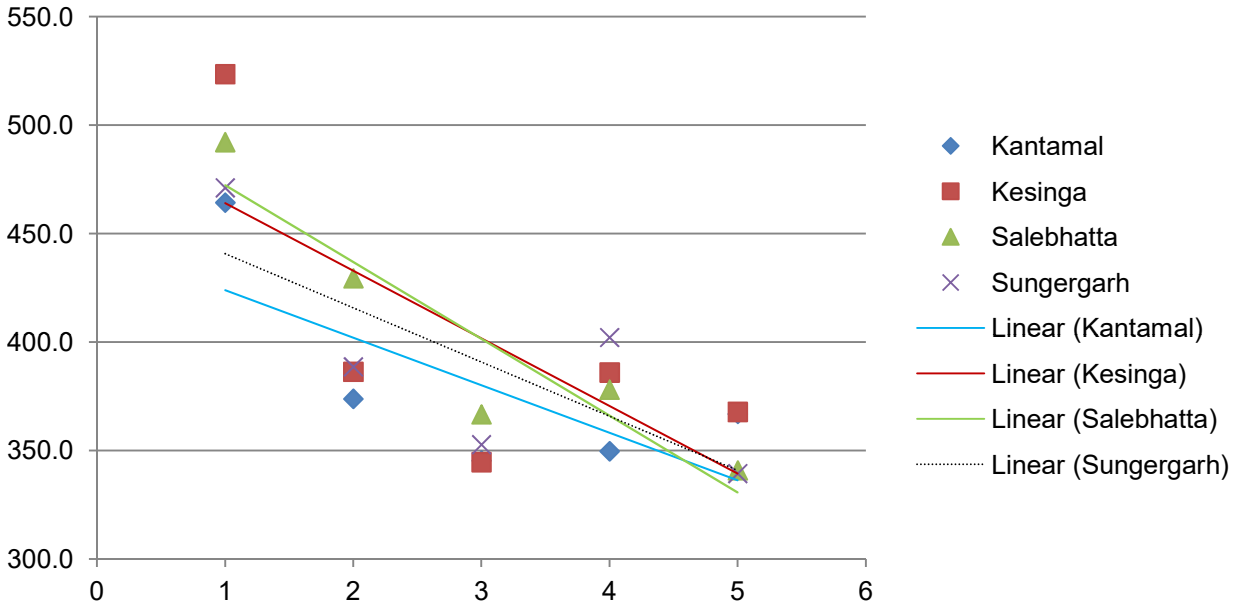
CanESM2_1960_2005_R1 & CanESM2_2006_2100_R1_RCP26

Decadal Rainfall variation



CanESM2_1960_2005_R1 & CanESM2_2006_2100_R1_RCP45

Decadal Rainfall variation



CanESM2_1960_2005_R1 & CanESM2_2006_2100_R1_RCP85

Rainfall-runoff model development using SWAT Model

- 5 years data for warming up

Calibration of Data

  - Kantamal 1978 -2000
  - Kesinga 1983-1990
  - Slaebhata 1978-1985
  - Sundergarh 1983-1992

- Rest of the data used for Validation

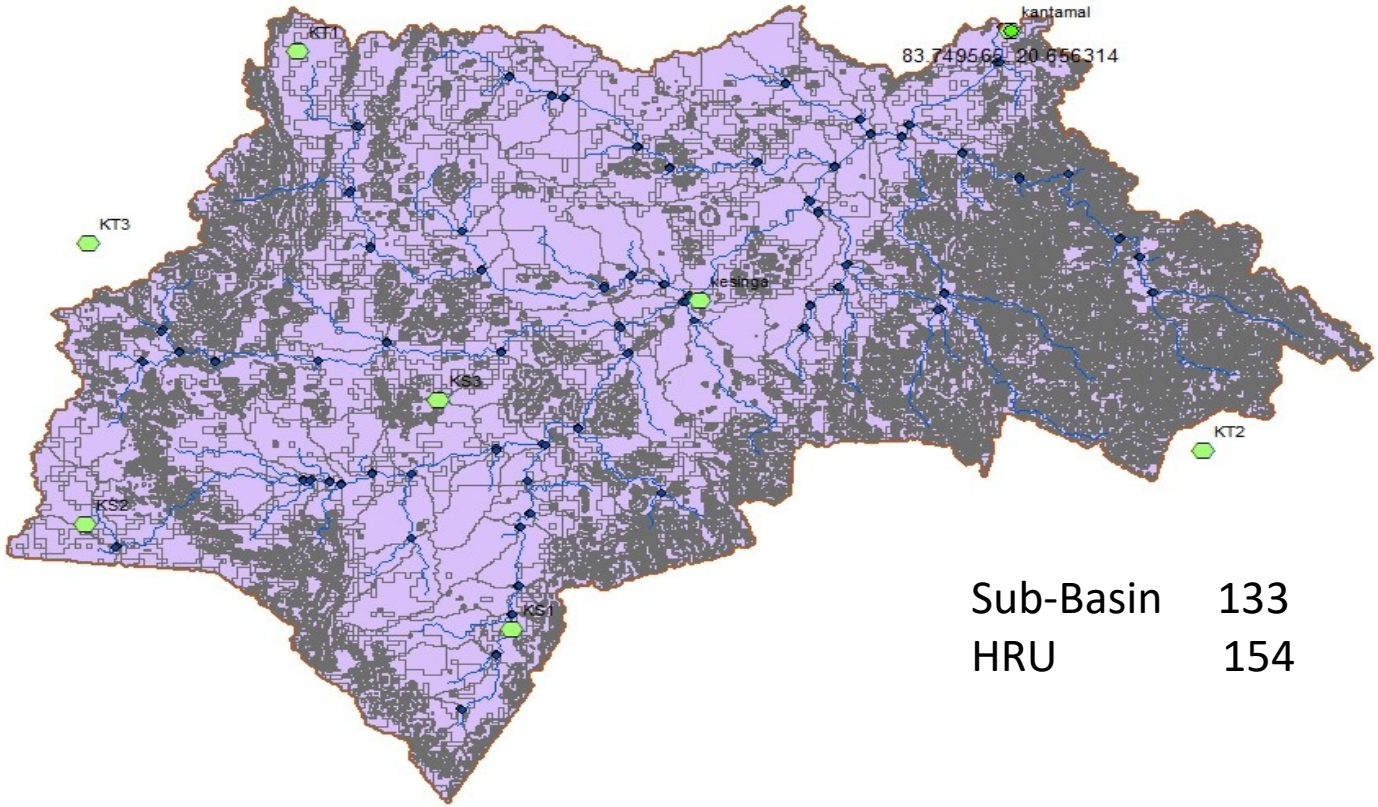
SWAT model development

Topographic information were derived using Digital Elevation Model (DEM) data (the SRTM DEM have been used).

The soil data available in NBSS&LUP, which contains soil maps at a 1:250,000 scale.

Calibration of the model was done by adopting the manual calibration procedure.

Kantamal basin map



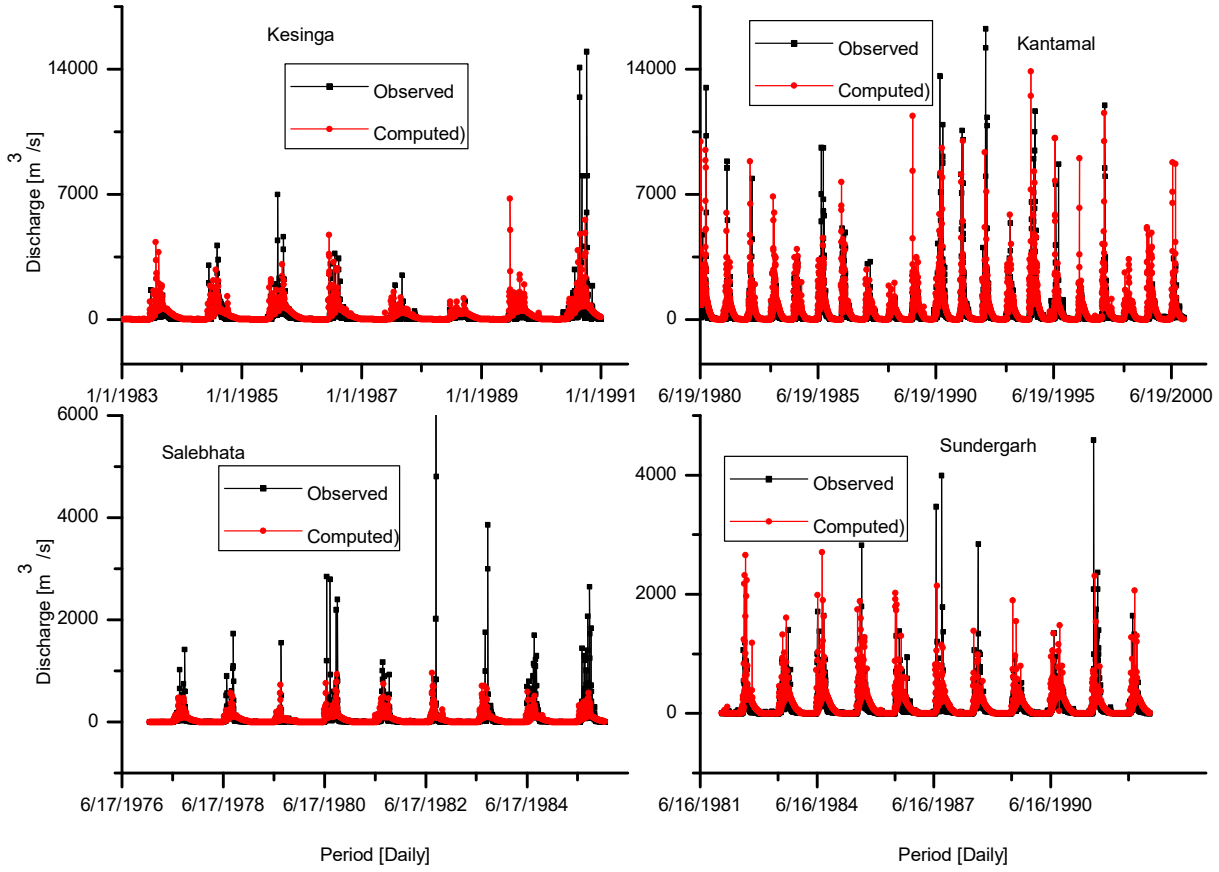
Sub-Basin 133

HRU 154

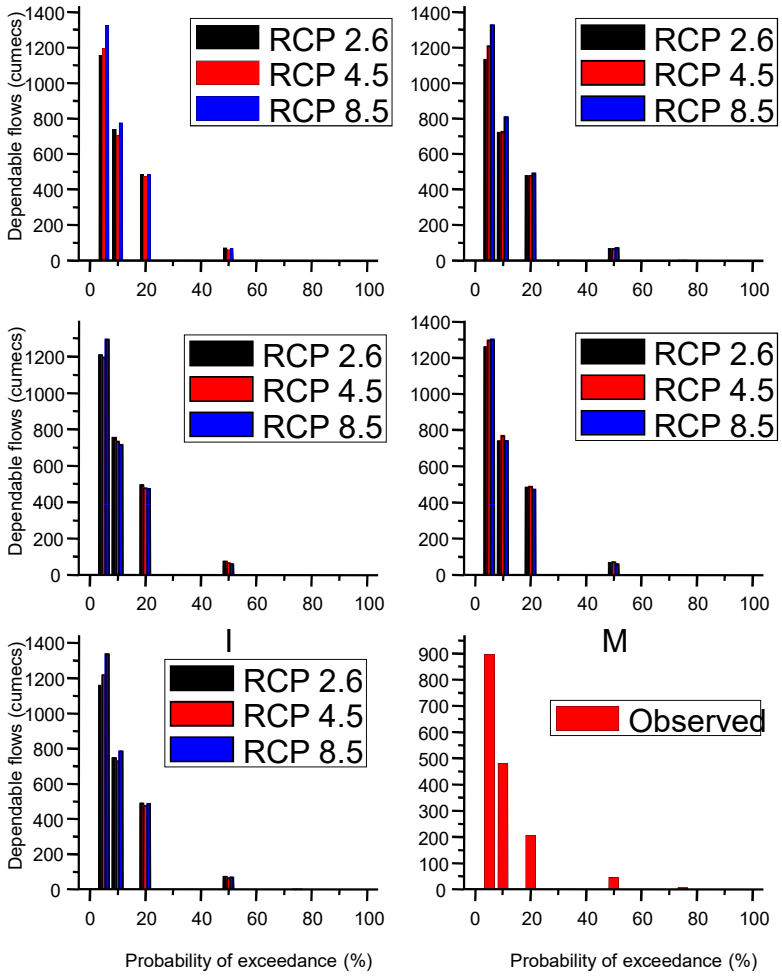
Calibrated Model Parameters

Parameter	Kantamal		Kesinga		Sundargarh		Salebhata	
	Calibrated values	Rank	Calibrated values	Rank	Calibrated values	Rank	Calibrated values	Rank
Alpha_Bf	0.95	6	6.84E-01	6	0.18	5	0.03	7
Cn2	76.40	1	81.70	1	76.10	2	85.10	1
Epco	0.42	9	0.82	9	0.61	1	0.00	10
Esco	0.04	4	0.77	4	0.65	4	0.12	4
Gw_Delay	3.00	10	7.38	10	5.33	6	0.00	9
Gwqmn	402.00	3	820.00	3	745.00	7	0.27	3
Rchrg_Dp	0.76	2	0.16	2	0.70	10	0.66	2
Sol_Awc	12.00	5	21.50	5	20.50	3	0.10	5
Sol_K	16.60	7	19.90	7	19.80	9	0.04	6
Surlag	0.92	8	0.00	8	0.25	8	0.02	8
NSE	0.78		0.82		0.76		0.63	

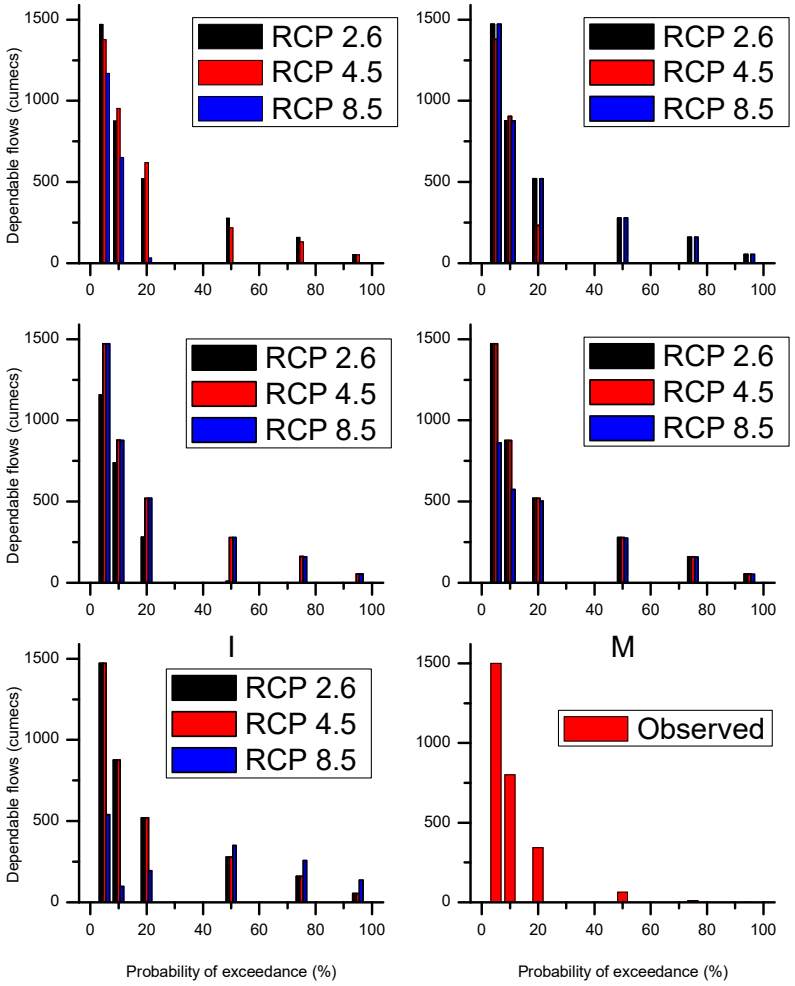
Observed and Computed plots during calibration period



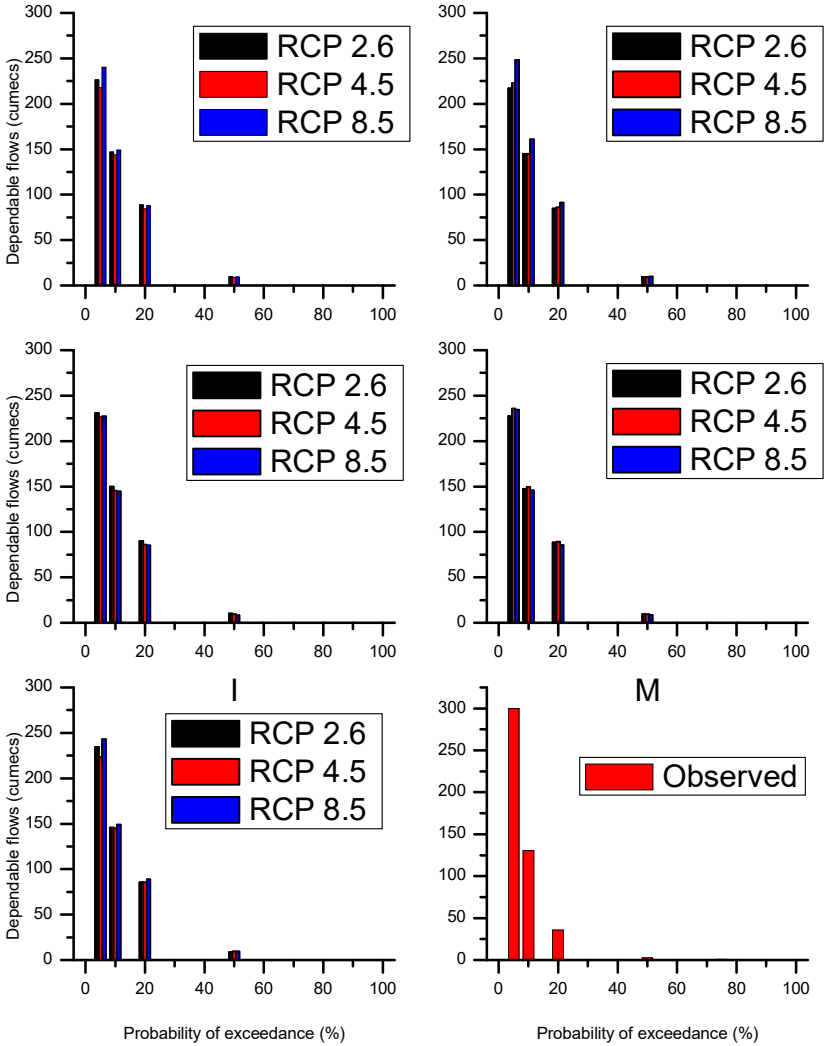
Future Water Resources Scenario – Dependable Flows at Kesinga



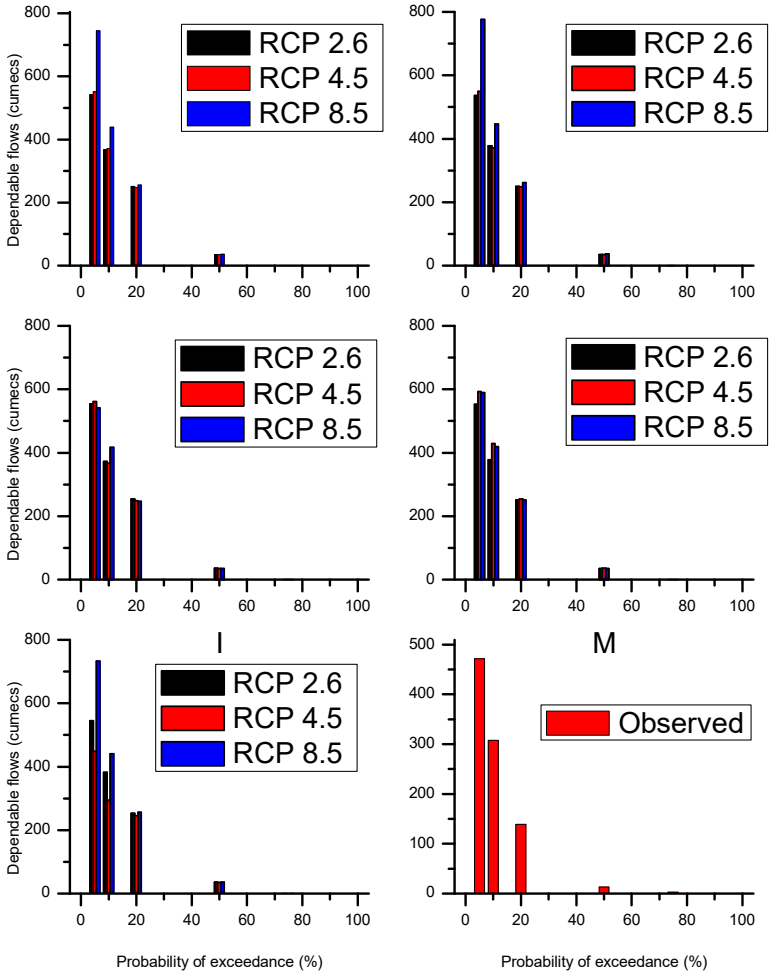
Future Water Resources Scenario – Dependable Flows at Kantamal



Future Water Resources Scenario – Dependable Flows at Salebhata



Future Water Resources Scenario – Dependable Flows at Sundergarh



Conclusions

- Sign test indicates that discharge is increasing except Ong tributary of Mahanadi River.
- Number of rainy days is decreasing for all sub-basins.
- Severe rainfall events are increasing for most of the basin except Ib tributary.
- Wavelet analysis indicated that there is change in rainfall pattern after 1980
- Decadal analysis of projected rainfall shows that there is decrease in rainfall for some scenarios 10 to 35 %.
- All the RCP scenarios show that there is an increase in flood in the future. It is shown that the RCP-2.6 and RCP-4.5 show moderate increase in the runoff, whereas RCP-8.5 shows significant increase.

THANKS