Assessment of impacts of climate change on runoff:
River Nzoia catchment, Kenya

by

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Objective

- To investigate the impact of climate change on runoff of Nzoia river catchment in Kenya (and other water balance components)

  To determine the relationships between rainfall, temperature and runoff on a seasonal/monthly basis.

Impacts

- Changes in variability, spatial patterns and seasonality of precipitation and changes in temperature will have the effect of changing the soil moisture, river runoff and groundwater recharge, peak runoff, basin hydrology.

yield of reservoir systems, water quality, water supply infrastructure, requirement of storage in water supply systems;

Impacts cont'

- Changes in sea level rise will cause loss of land due to saline intrusion into coastal aquifers and movement of salt-front estuaries affecting freshwater abstraction points.

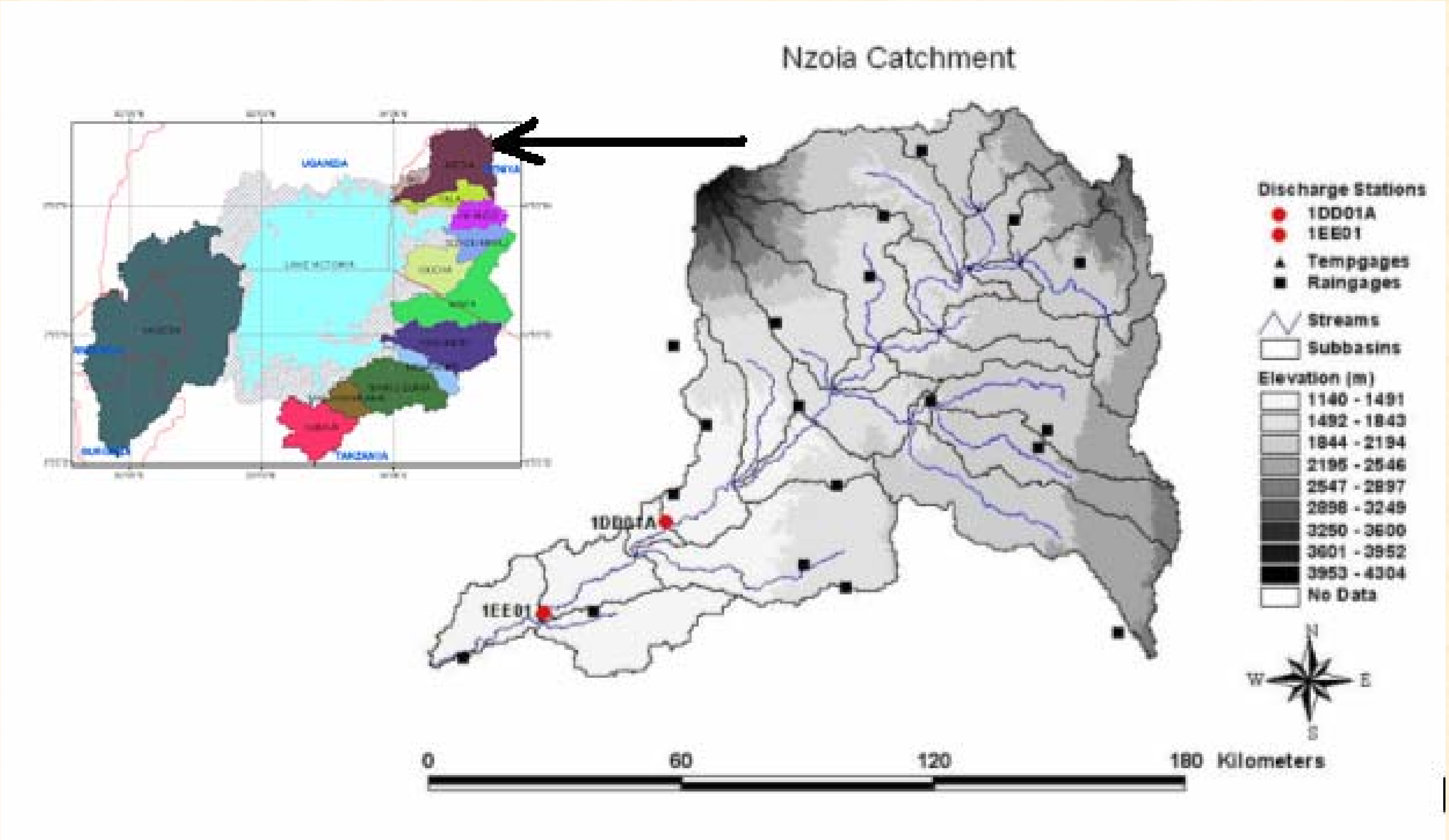
reduced water quality and ground water abstractions

- An increase in temperature could result in faster plant growth and increased transpiration.

Increased evaporation from lakes and reservoirs, reduced runoff and reduced groundwater recharge, higher demand for water for irrigation, bathing and cooling due to increased temperatures

among many others………

Study area



Nzoia Catchment
UGANDA
KENYA
LAKE VICTORIA
TANZANIA
BURUNDI
1DD01A
1EE01
Discharge Stations
1DD01A
1EE01
Tempgages
Raingages
Streams
Subbasins
Elevation (m)
1140 - 1491
1492 - 1843
1844 - 2194
2195 - 2546
2547 - 2897
2898 - 3249
3250 - 3600
3601 - 3952
3953 - 4304
No Data
N
W
E
S
0
60
120
180
Kilometers

Study area

- River Nzoia has a catchment area of 12,709 km^2 with a length of 334 km up to its outfall into Lake Victoria.

- The mean annual rainfall varies from a minimum of 1076 mm to a maximum of 2235 mm with a catchment average of 1424 mm.

Data

DATA TYPE	SOURCE
Rainfall, maximum and minimum temperatures, radiation, wind speed, relative humidity	Kenya Meteorological Department GCM (CGCM2 model) IPCC
River discharge	Ministry of Water and Irrigation
Land cover data	Food and Agricultural Organization, FAO-Africover project.
Soil data	International Soil Resource and Information Centre (ISRIC) in conjunction with Kenya Soil Survey
Digital Elevation Model (DEM)	Shuttle Radar Topography Mission (SRTM), USA.

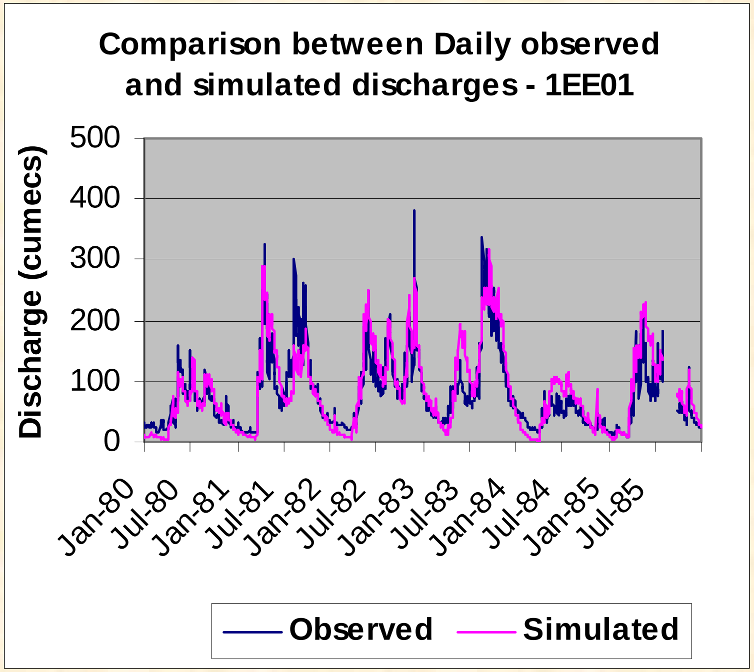
Methodology

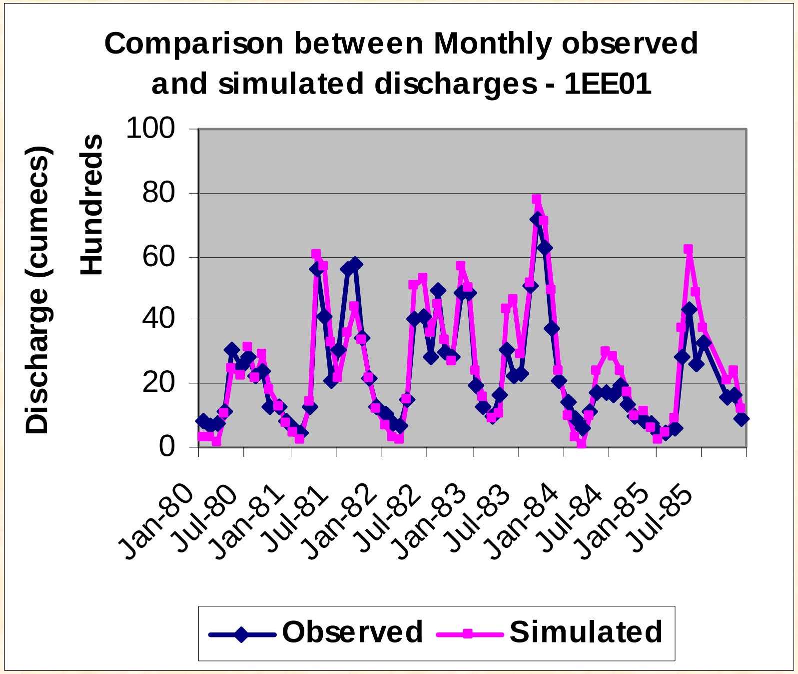
- Hydrological Model: - SWAT2005
- GCM: – CGCM2 (Canadian Center for Climate Modelling and Analysis (CCCma); scenarios A2 and B2 (as described in IPCC)
- Weather generator: – LARS-WG Rothamsted Research, UK
  3 weather stations: - Kakamega, Kitale and Eldoret

Results

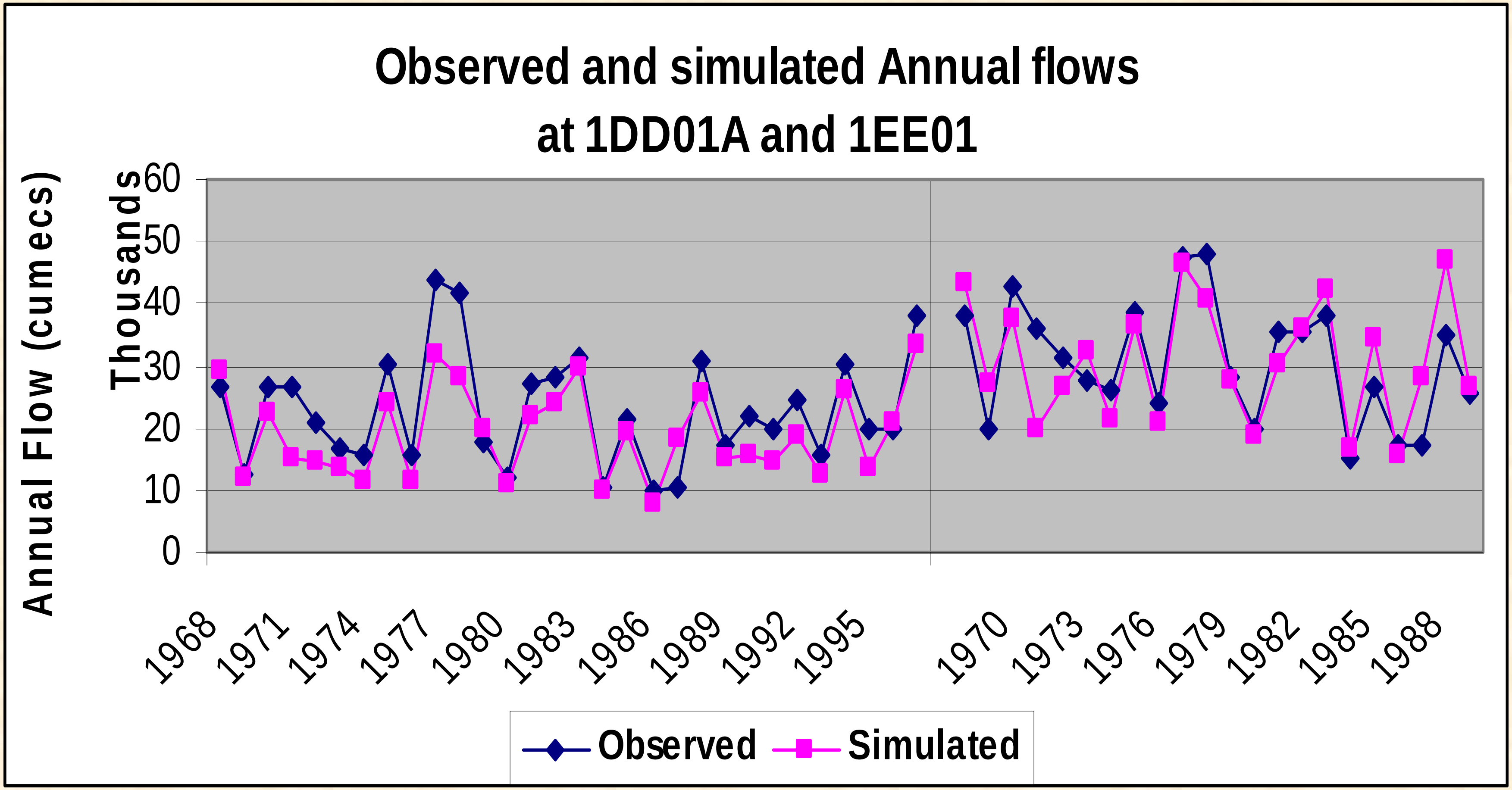
- Evaluation of SWAT2005

1) Calibration 1980-1985





2) Long term evaluation



Results cont'd

Calibration

	Observed		Simulated			
	Mean (cumecs)	Standard Deviation	Mean (cumecs)	Standard Deviation	NSE	R^2
Daily	76	59	84	66	0.71	0.78
Monthly	76	53	83	63	0.76	0.84

Long term

	Observed		Simulated			
	Mean (cumecs)	Standard Deviation	Mean (cumecs)	Standard Deviation	NSE	R^2
Daily	90	60	97	66	0.55	0.65
Monthly	87	56	90	63	0.71	0.76

GCM / LARS-WG

Station	Calibration period	Validation period
Kakamega	1981-1995	1996-1999
Kitale	1981-1995	1996-1999
Eldoret	1977-1990	1991-1999

	Rainfall		Temperature	
	Calibration	Validation	Calibration	Validation
Kakamega	0.94	0.82	0.97	0.92
Kitale	0.88	0.74	0.97	0.83
Eldoret	0.89	0.83	0.95	0.91

CGCM2 scenarios

- 1961-1990 as the baseline and the time slices 2010-2039 and 2040-2069 representing the 2020s and 2050s respectively.
- Rainfall - the highest changes in December which shows increases in both scenarios in the 2020s and 2050s.
- Temperatures increases in both scenarios in the

2020s are about 0.85^{o}C

2050s - 1.69^{o}C (A2 scenario) and 1.37^{o}C (B2 scenario)

- The highest temperature increases are observed in the months June and July which are normally the cold season.

Changes in runoff

In general the A2 scenario is seen to yield more than the B2 scenario for the 2020s whereas in the 2050s the percentage changes are similar for both scenarios.

In 2050s, the A2 scenario is much warmer than B2 (by 0.32^{o}C) but the changes in rainfall are similar and this leads to similar changes in runoff.

This shows that the difference in temperature in this case does not yield significant changes in the catchment yields.

- A2 scenario has increased the surface runoff and base flow by

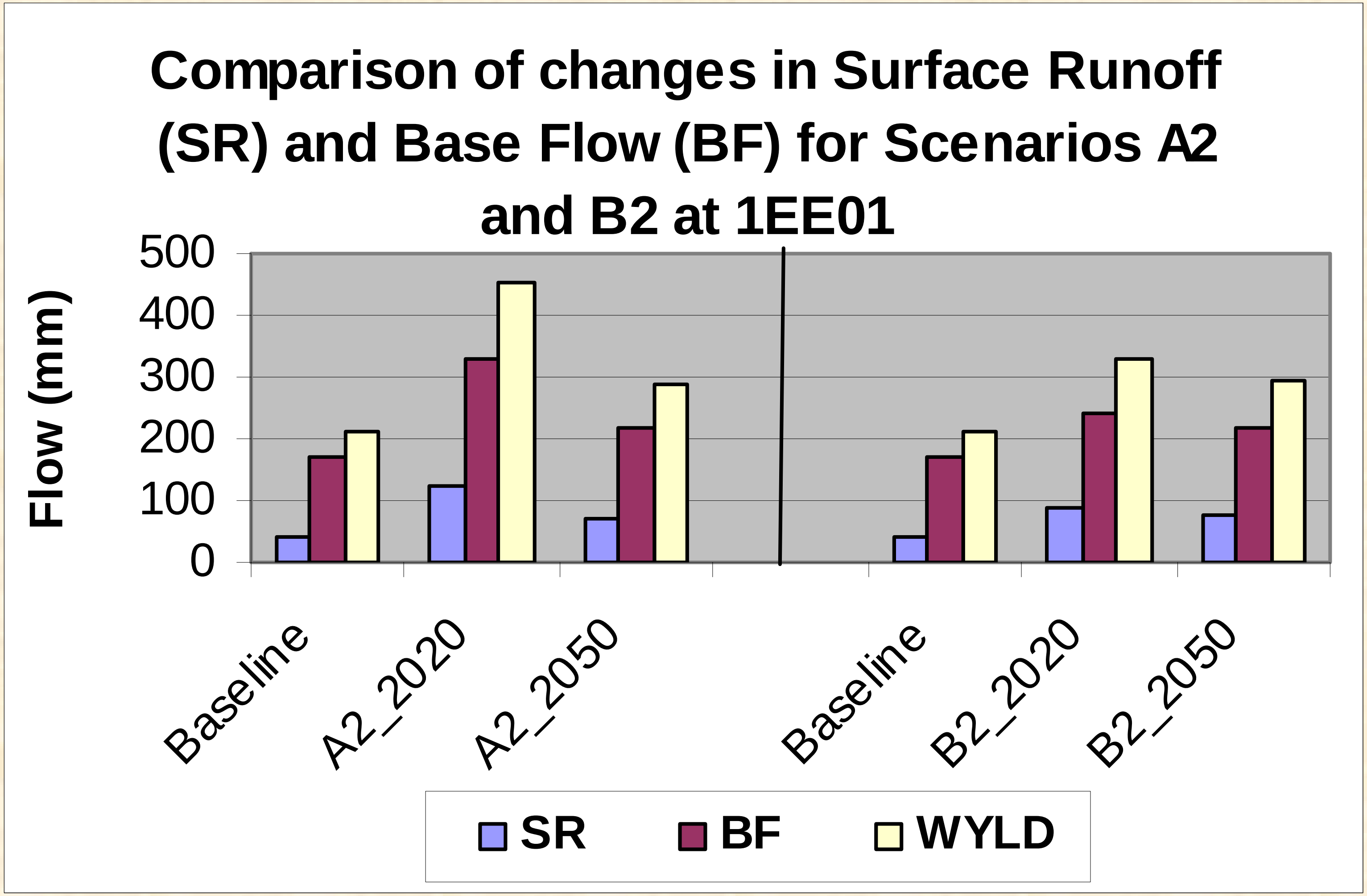
2020s - 187% and 94%

2050s - 67% and 26%

- B2 scenario has increased the surface runoff and base flow by

2020s - 100% and 41%

2050s - 69% and 27%

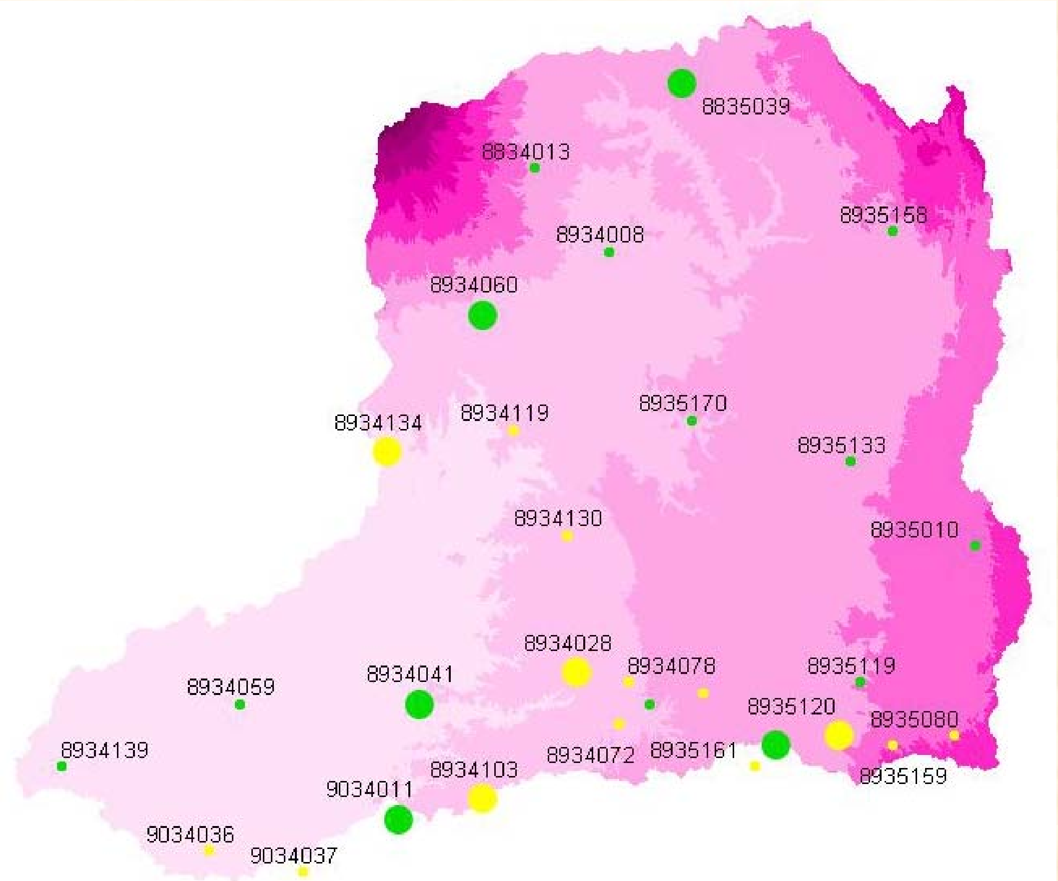

Comparison of changes in Surface Runoff (SR) and Base Flow (BF) for Scenarios A2 and B2 at 1EE01
Flow (mm)
500
400
300
200
100
0
Baseline
A2_2020
A2_2050
Baseline
B2_2020
B2_2050
SR
BF
WYLD

Time series analysis - over the last 40 years, rainfall amounts have increased by about 2.3mm/year

and mean temperature by about

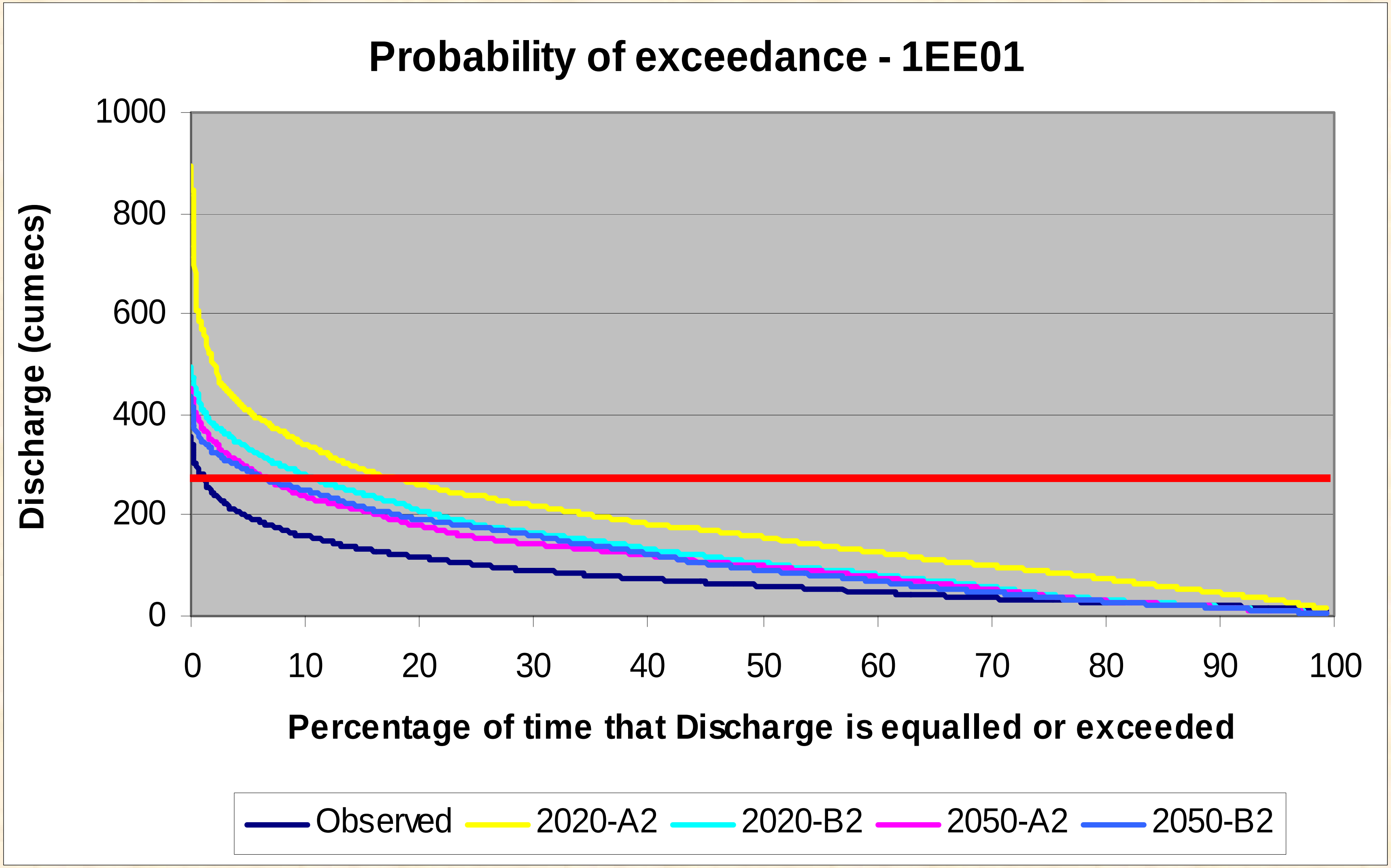
0.21 - 0.79^{o}C

since 1990.



Green- increase in rainfall,

yellow – decrease in rainfall



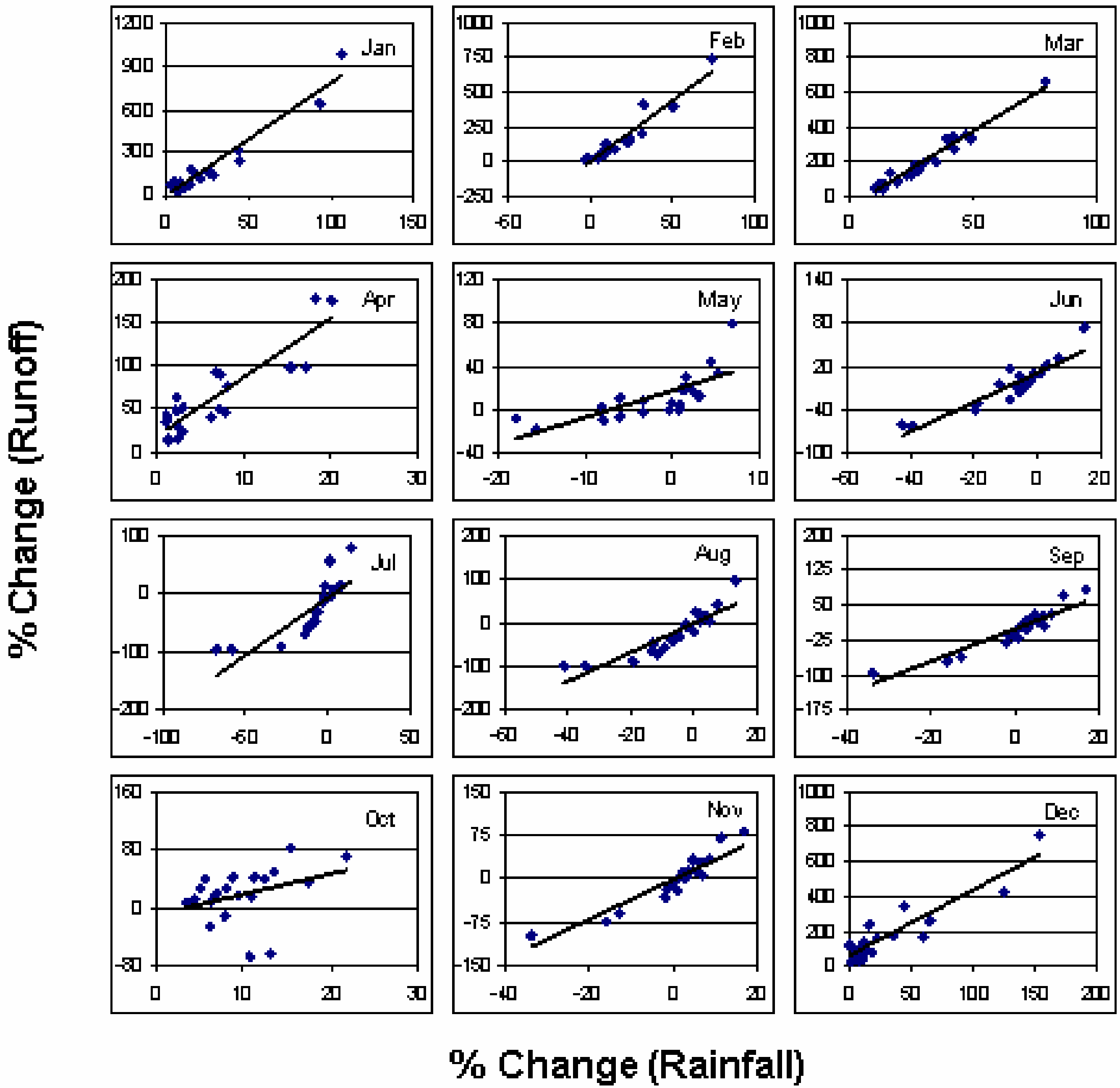
RED line is the bankfull discharge

- Other GCMs considered

  CCSR96, CSI296, ECH498, GFDL and HAD300

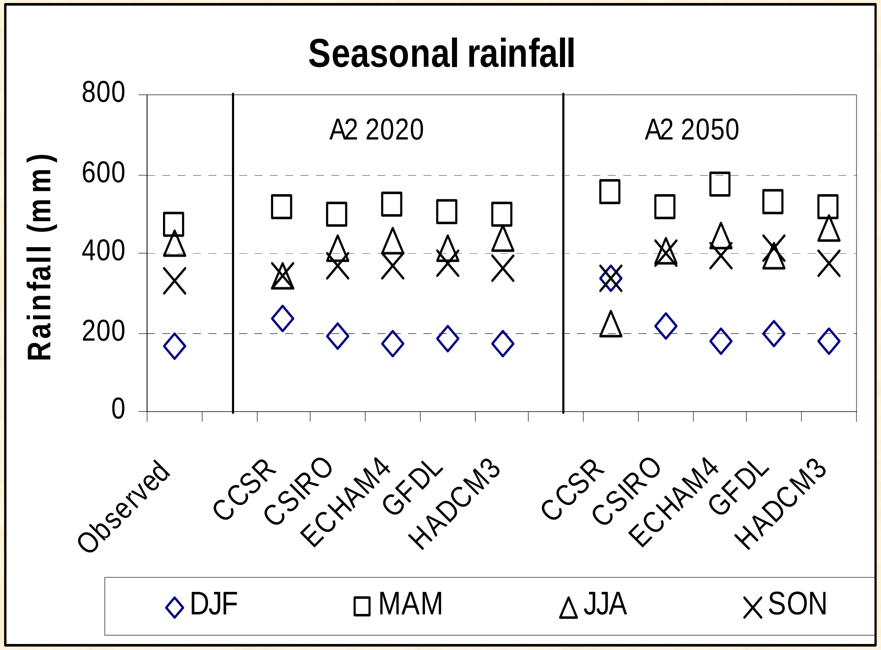
Annual % changes

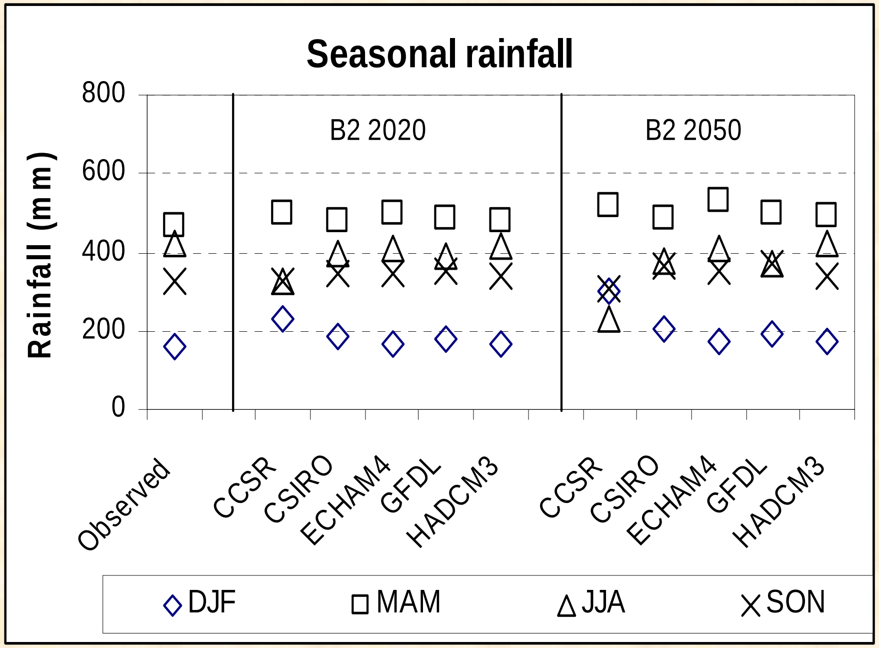
	runoff				Base flow			
	2020		2050		2020		2050	
	A2	B2	A2	B2	A2	B2	A2	B2
CCSR	46	6	93	27	4	-15	-8	-28
CSIRO	44	11	84	21	19	1	29	0
ECHAM4	56	20	115	42	28	8	50	15
GFDL	45	10	84	22	21	1	29	1
HADCM3	38	7	65	11	20	2	32	3
CGCM2	**187**	**100**	**67**	**69**	**94**	**41**	**26**	**27**


% Change (Runoff)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
% Change (Rainfall)

Seasonal rainfall

MAM and DJF are maintained. JJA and SON show shifts





Due to shifts in seasonal patterns =>

- Affects agriculture; water resources; industries etc.

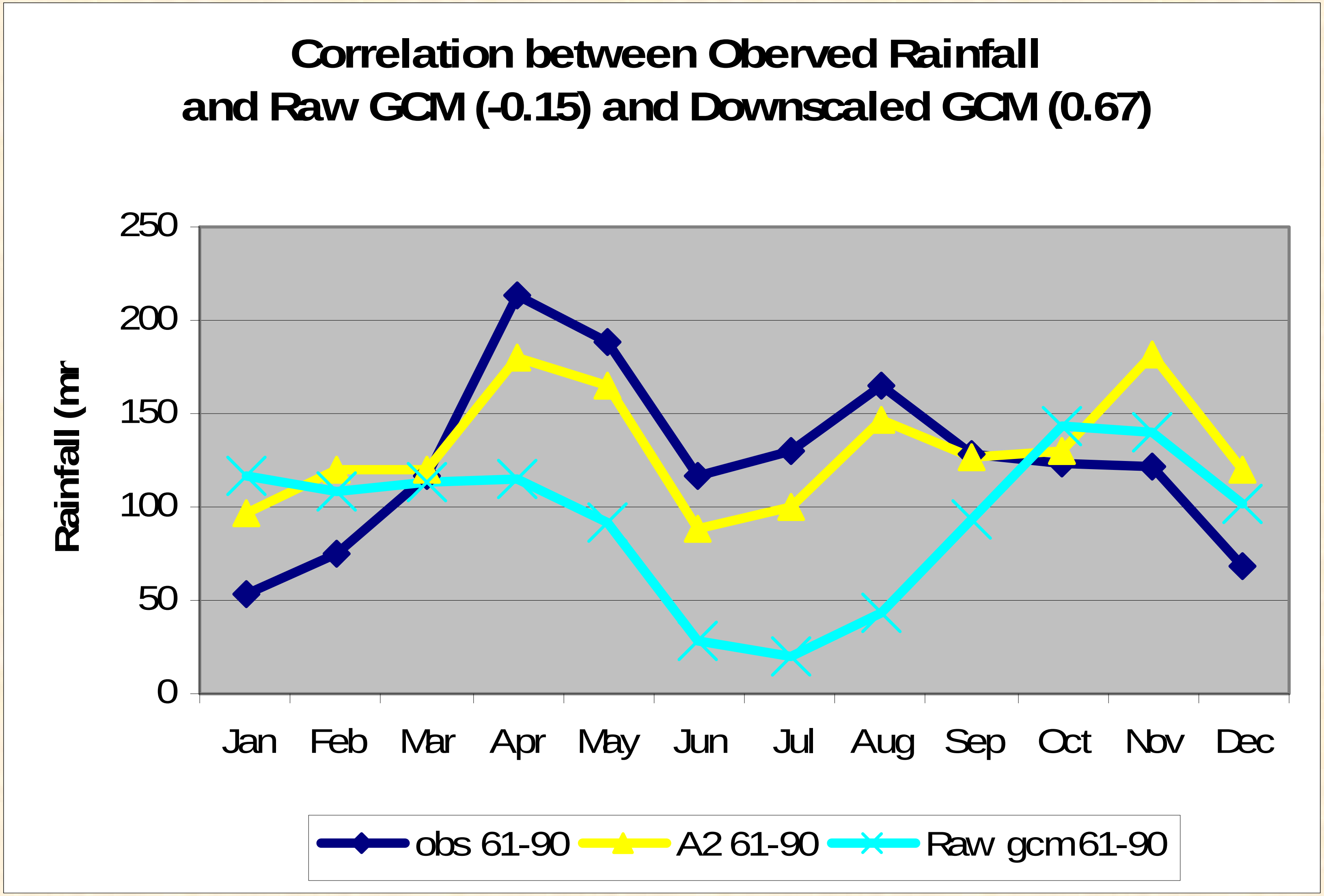
planting seasons, types of crops grown, emergence of diseases where none existed before, change in land management systems among others

- The simulation results have shown that if all other variables are held constant, a significant increase in river discharge may be expected in the coming decades as a consequence of increased rainfall amounts.
- Many climate models can to be used to provide a wider range of possible outcomes especially for planning purposes.

Challenges

- GCM downscaling to regional scale
- RCMs not yet available for this region

  Different scenarios give quite varied projections especially for rainfall in this region
- Uncertainty inherent in the climate models; model used for impact assessment – parameterisation
- Uncertainty in the data itself



Correlation between Oberved Rainfall
and Raw GCM (-0.15) and Downscaled GCM (0.67)
Rainfall (mr
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
obs 61-90
A2 61-90
Raw gcm61-90