Assessment of Runoff Generation at Rift Valley Lakes Basin of Ethiopia for present and future climate scenario

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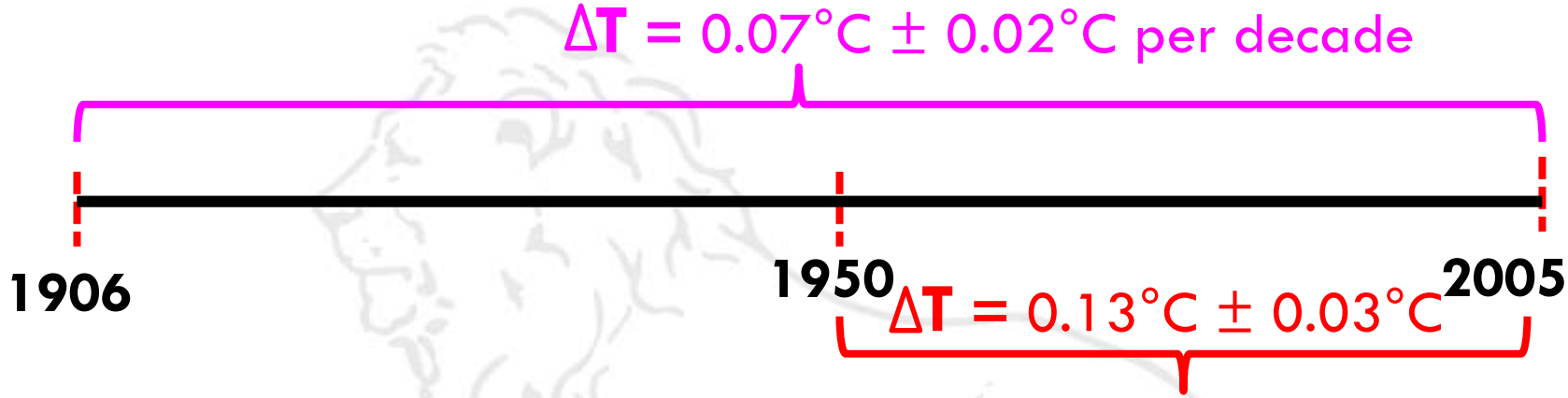
INTRODUCTION

- The natural environment is under tremendous stress as a consequence of various demands of increasing population.
- Temporal and spatial patterns of precipitation and extreme flows have been changing in the recent past.
- Global water balance is highly influenced…
- Increased earth and sea surface temp., melting of polar ice, rise in average global ocean level…

(Loaiciga et al., 1996; Singh et al., 1997; Barnett et al., 2005; Steele-Dunne et al., 2008; IPCC,2007)

Introduction…

- Avg. temp. rise of 0.6 ± 0.2 °C (1860-2000) versus 0.74°C ± 0.18°C (1906-2000) (IPCC,2001; 2007)



- Anthropogenic induced land use/cover changes have transformed 1/3rd -1/4th of ice-free surface of our planet (Vitousek, 1994; Vitousek et al., 1997).
- Land use/land cover changes significantly altered bulk water yield from the watershed.

Introduction…

- Land use changes are significant in tropical regions (Piao et al. 2007).
- Currently, 1/4th of the population of Africa is facing high water stress and this magnitude is expected to increase (2-3 fold) in the next 40 years (Boko et al., 2007)
- Adaptation mechanisms developed by African farmers are not sufficient enough to cope up with current and future climate variability (IPCC, 2007)

Introduction…

- The sub-Saharan region of Africa has been challenged by both man-made and natural stresses …. (Tadross et al., 2005; You and Ringler, 2010).
- Key Features - prolonged drought
  - severe and unprecedented flood
  - poor economic developments
  - poor institutional developments
- Ethiopia is a victim of such global challenges
- Example: **48 flood** and **12 drought** events over the last Century (EM-DAT, 2010).

Introduction…

Ethiopia: Agricultural sector accounts

- 45% of the country's GDP
- 85% of the export revenue
- Employs 80% of labour force.
- Major source of subsistence and [illegible] income for majority of the rural population.
- Agricultural production is mainly rain-fed.

Introduction…

- Owing to limited data availability, little attempt has been made, in the past, to understand the watershed dynamics of Ethiopian basins in response to changing climate and catchment conditions.
- The Rift Valley lakes and rivers system of Ethiopia has undergone major changes in recent past.
- Agricultural, water supply, and hydropower sectors are affected by variable climate patterns.

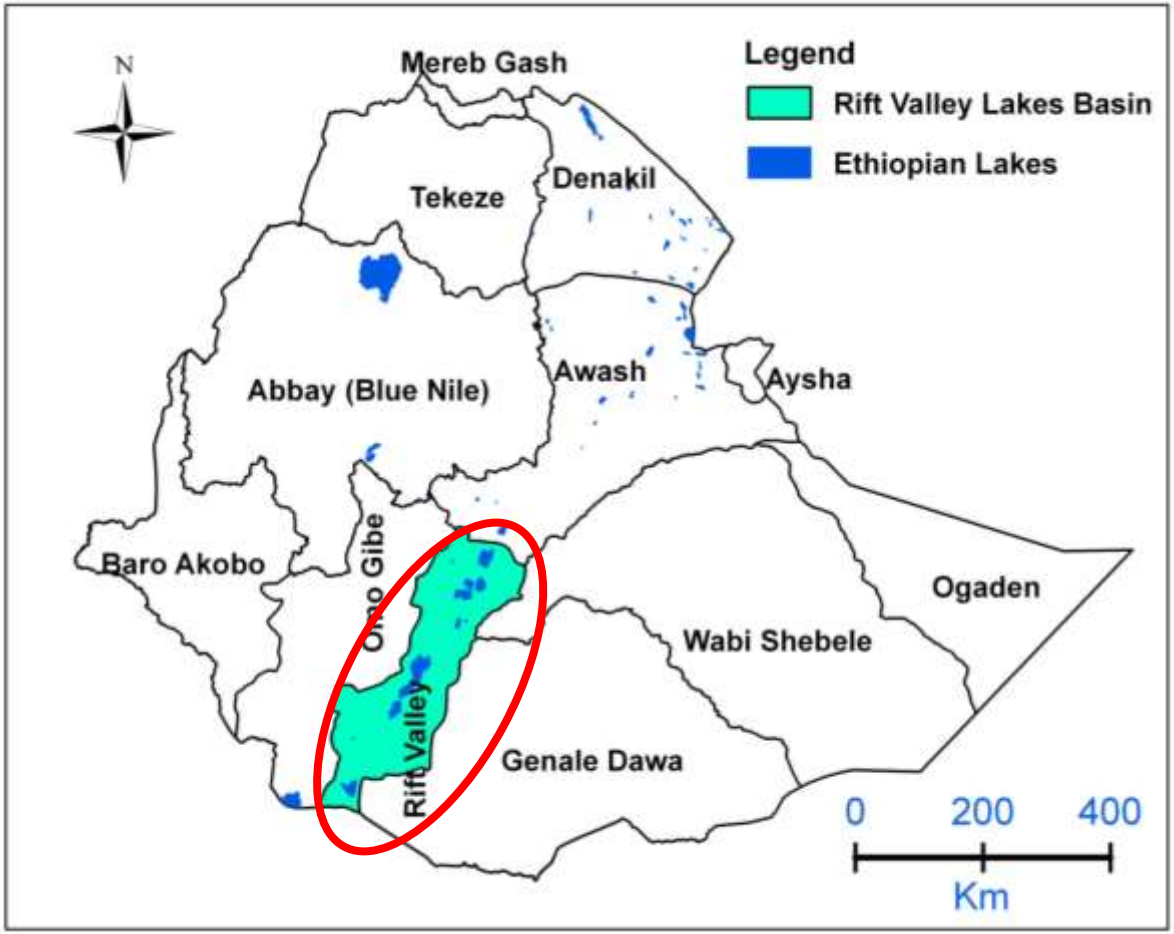
Key Objectives

- Explore the impact of large scale present and future climatic variables under different greenhouse gas forcing on local climate at Rift Valley lakes basin of Ethiopia.
- Simulate runoff at desired locations using bias corrected precipitation and temperature in two snow free, agricultural watersheds in the basin.
- Forecast the likely future climate implications in the basin.

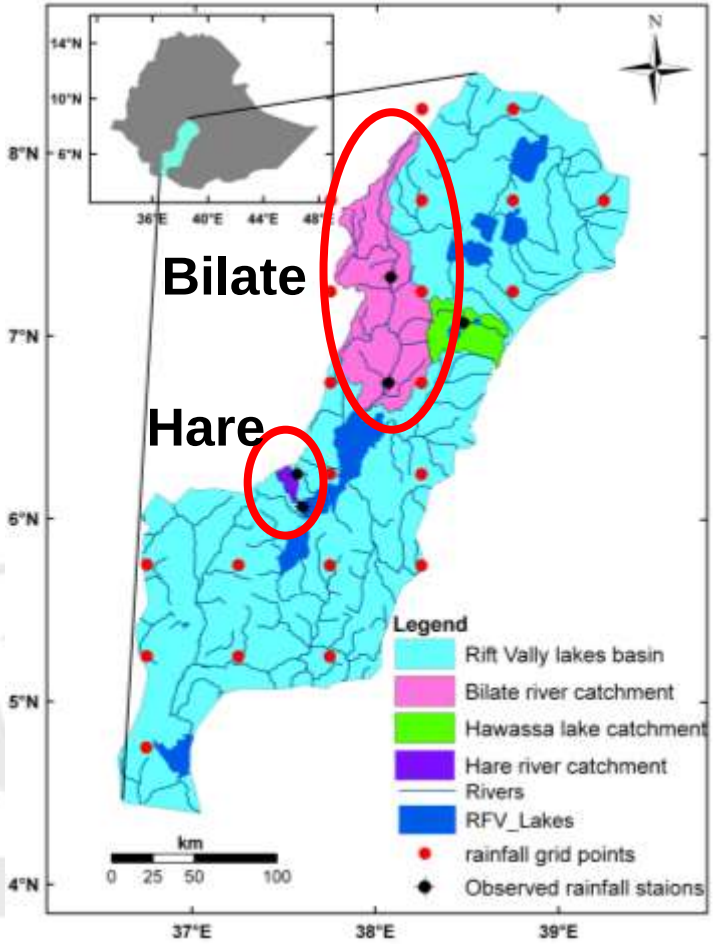
STUDY AREA

- The study mainly focuses on Rift Valley lakes Basin of Ethiopia.
- **Geog. location:** 4^{o}24’29” to 8^{o}26’38‘’ N latitude and 36^{o}35’45” to 39^{o}23‘31” E longitude.
- **Mean annual rainfall:** 600-1220 mm
- **Temperature:** Avg. temp. varies from 10.3 ^{o}C (min.) to 30.6 ^{o}C (max.)
- **Climate Condition:** sub-humid to moderate tropical semi-arid.
- Gemorphology: lowland plateau & escarpments
- Study Watersheds: Bilate (5330 km^2) and Hare (166.5 km^2)

River Basins of Ethiopia & Study Watersheds

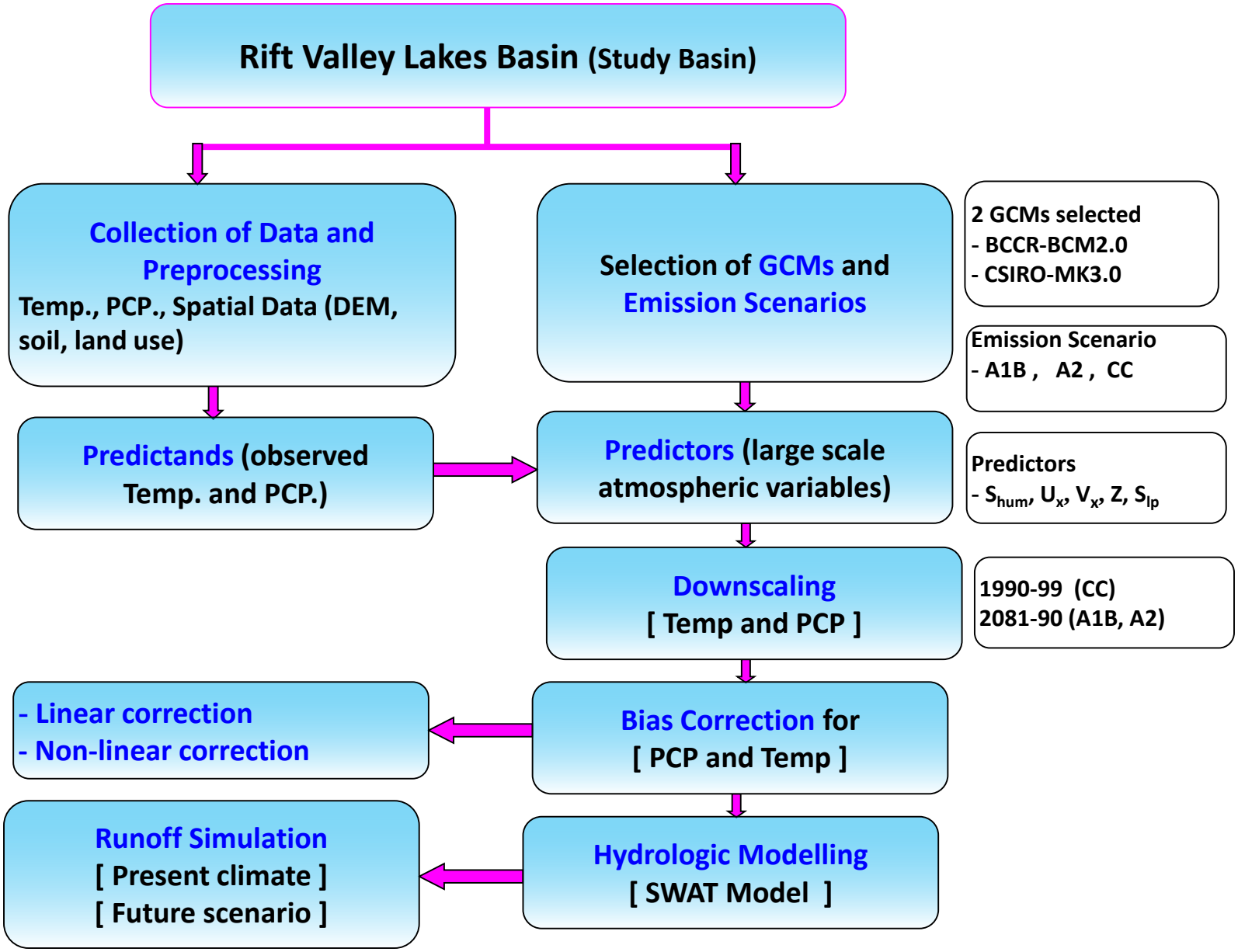


12 major river Basins



Bilate (5330km^2) and Hare (166.5 km^2)

Methodology

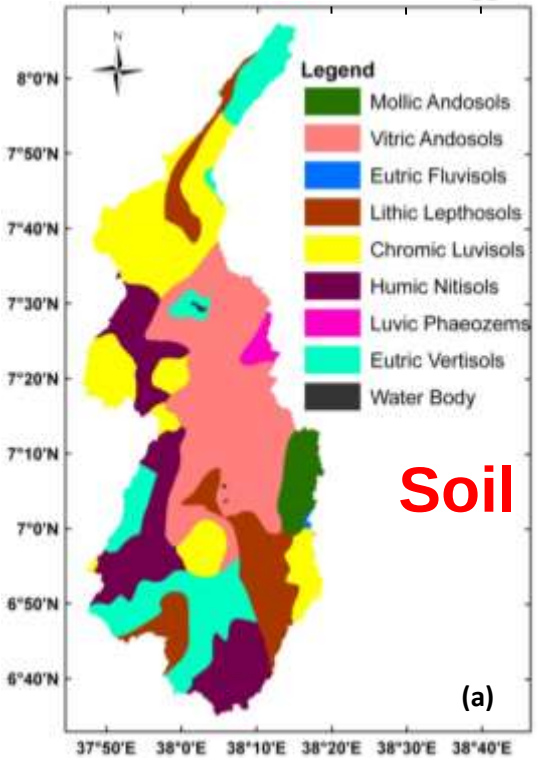


Dataset Used

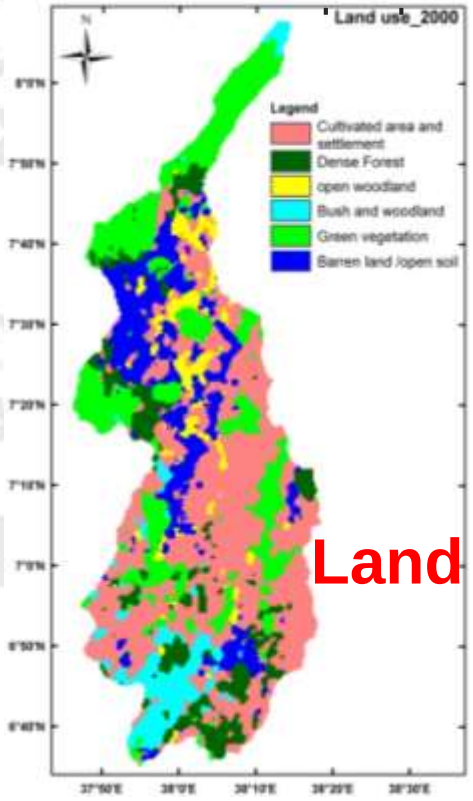
- Observed daily precipitation and temperature data from 1980-2009.
- Daily Global Climate Model (GCM) Variables for current climate (1971-1999) and
- Daily GCM Variables for future climate condition (2081-2090).

Data Used (Bilate and Hare watersheds)

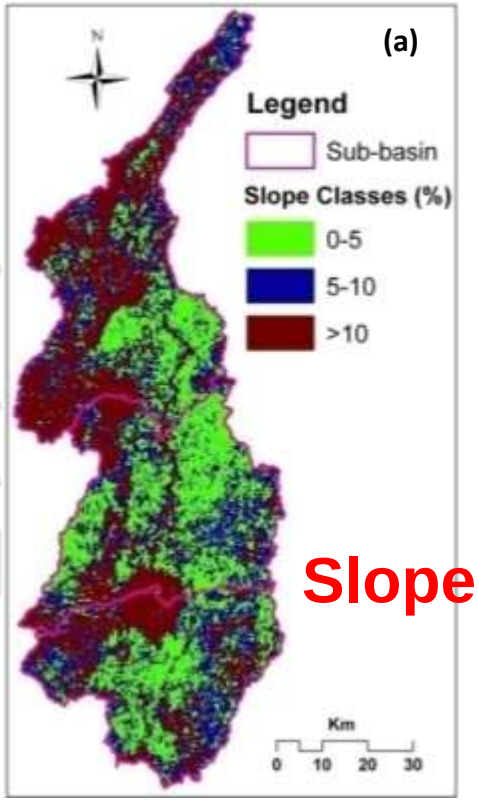
- Topographic Data (90m SRTM DEMs)
- Hydrometerological Data (Daily RF, Temp., RH, Sunshine and Streamflow)
- Soil Data (FAO soil data); Land Use Data (Landsat image)



Soil

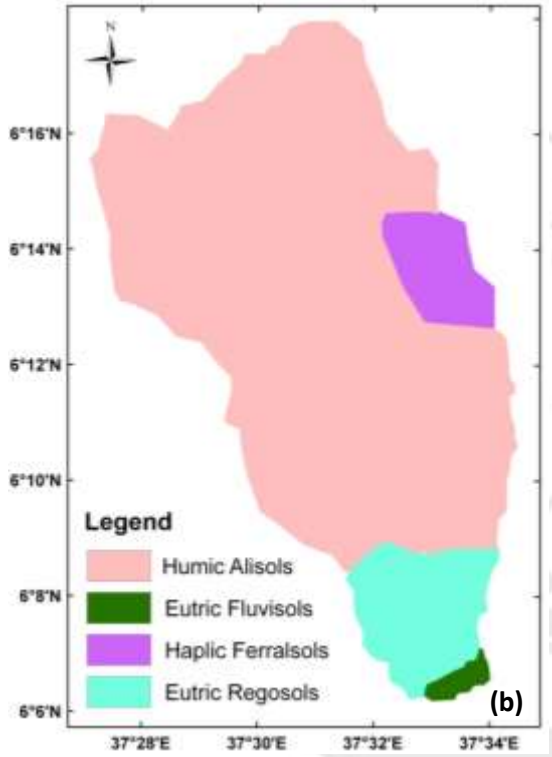


Land use

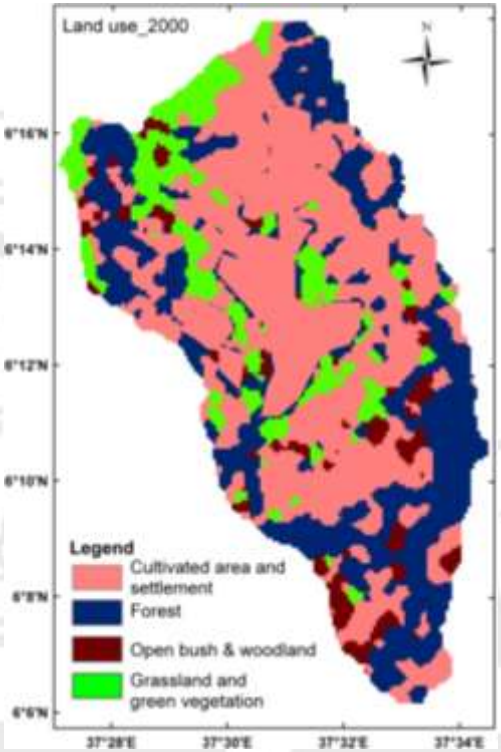


Slope

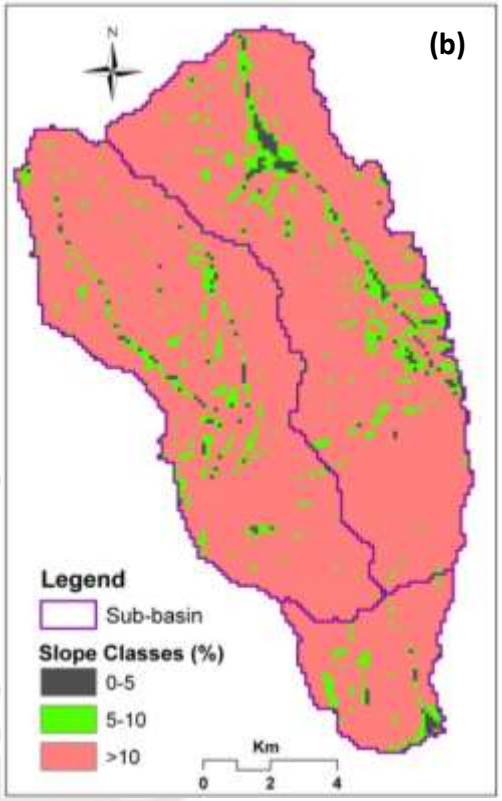
Soil Land use and Slope classes



Soil



Land Use



Slope

GCMs Selected and Scenario Used

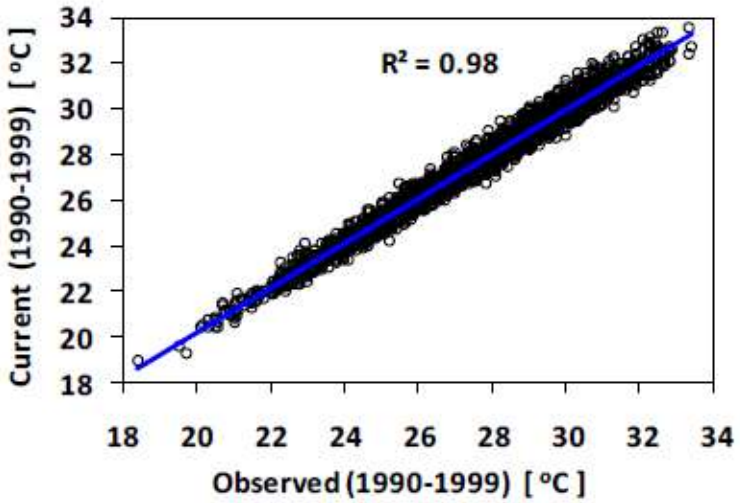
- **BCCR-BCM2.0 (**Bjerknes Center for Climate Research Version 2.0 of Norway)
  - Atmospheric resolution of T63 (1.9^ox1.9^o)
  - Oceanic resolution of 0.5^o-1.5^o x 1.5^o
- **CSIRO-MK3.0** (Commonwealth Scientific and Industrial Research Organization of Australia)
  - Atmospheric resolution of T63 (1.9^ox1.9^o)
  - Oceanic resolution of 0.9^ox1.9^o.
- **Emission Scenarios Used:** A1B, A2 and Current Climate condition

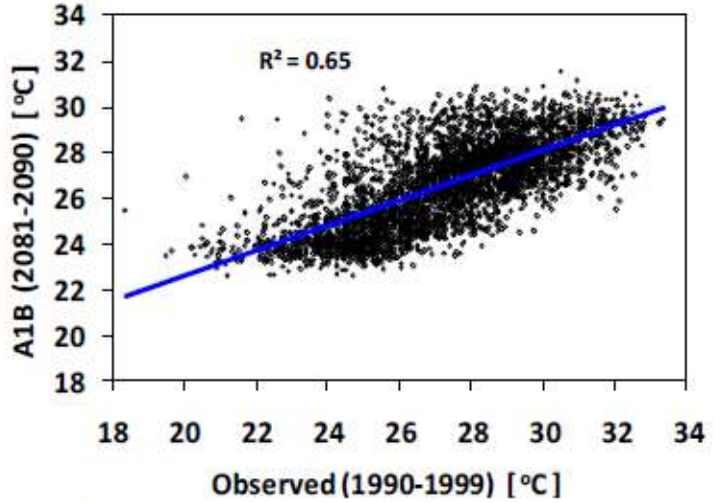
A1B – medium forcing, CO_2 conc. 720 ppm in 2100 (Balanced World)
A2 – high forcing , CO_2 conc. 820ppm in 2100 (Heterogeneous World)

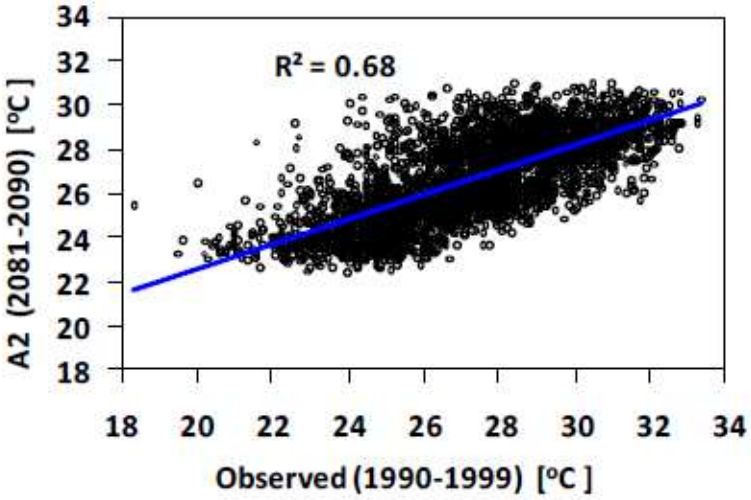
Temperature downscaling

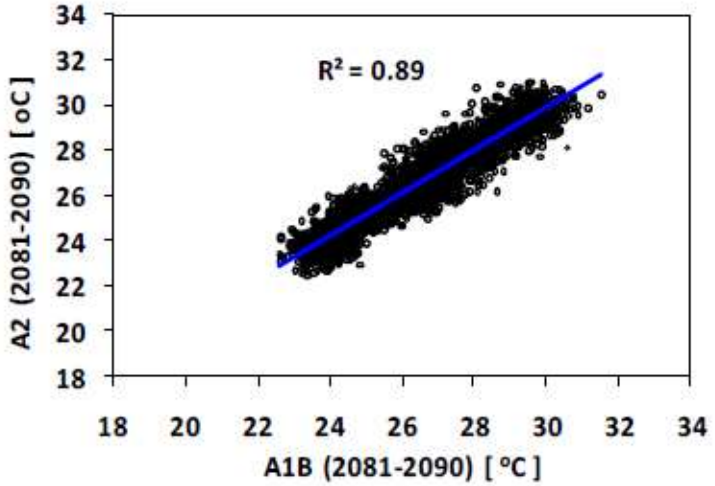
- Downscaled temperature show modest agreement to the observed series.
- Regression , quantile plot and Q-Q plot is conducted to verify the validity of simulated current climate condition.

Observed Temp. versus downscaled (Regression)

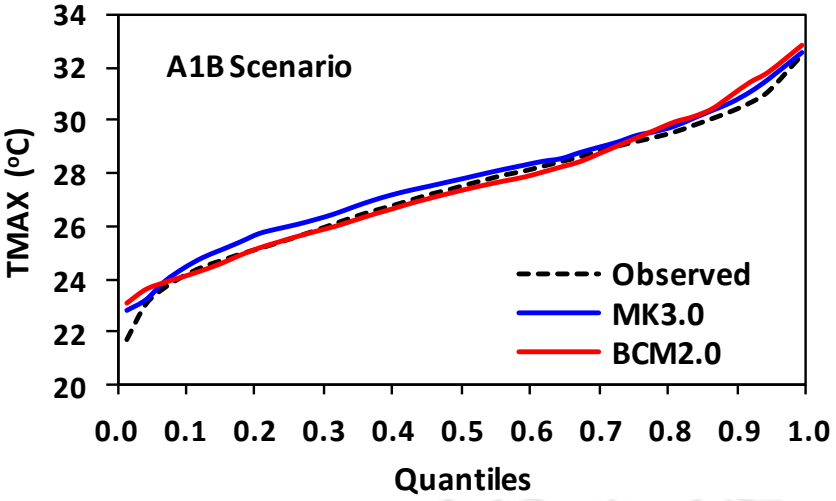


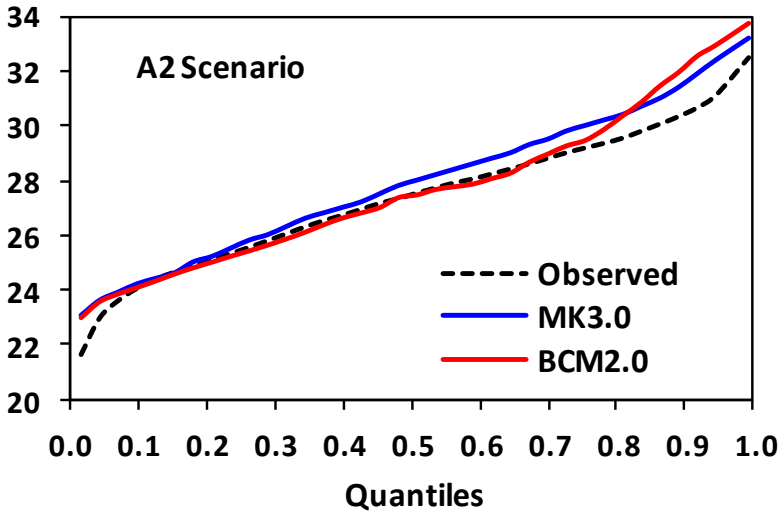


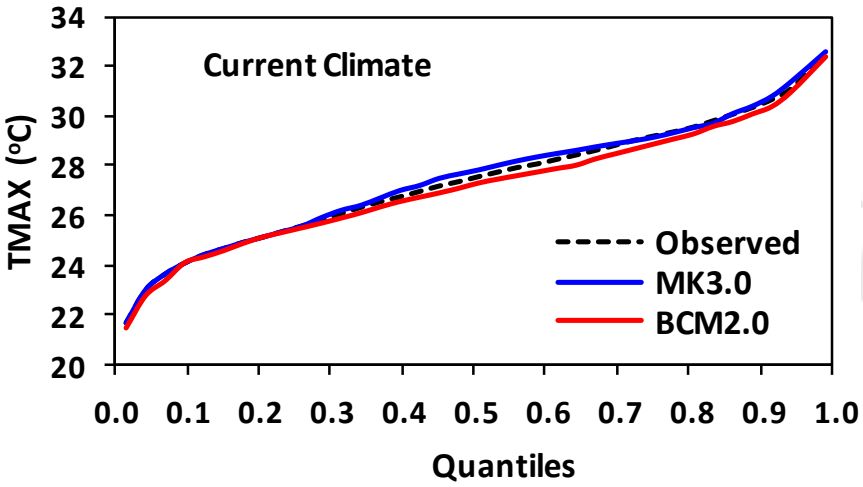




Quantile plot of temp. for two GCM realizations

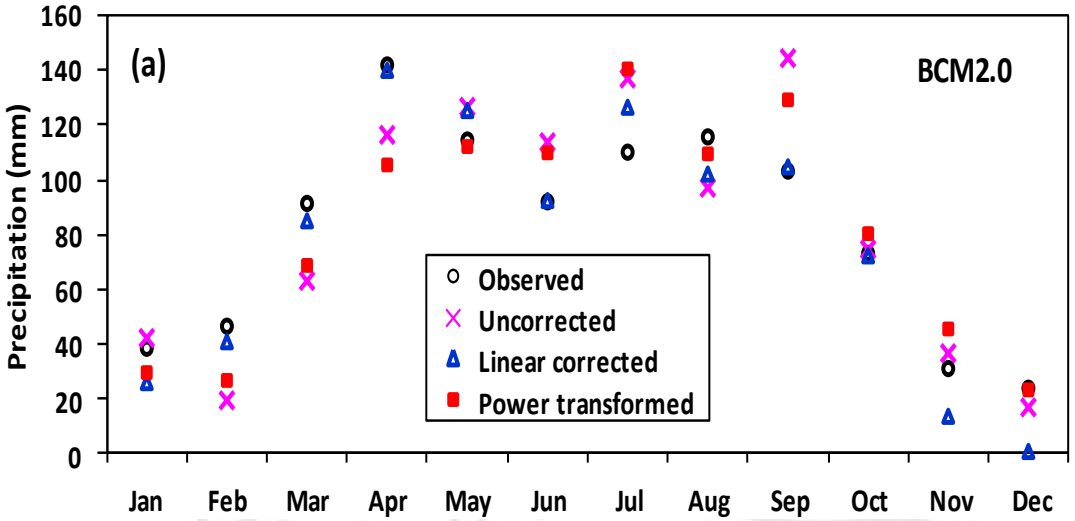


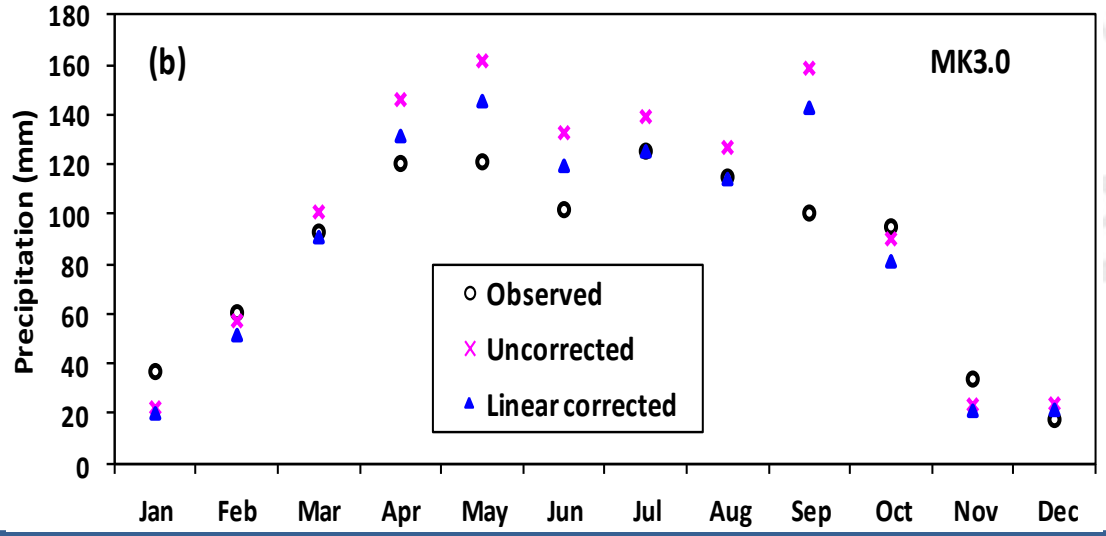




The quantile plots are S-shaped and are characteristic example of bell-shaped distribution.

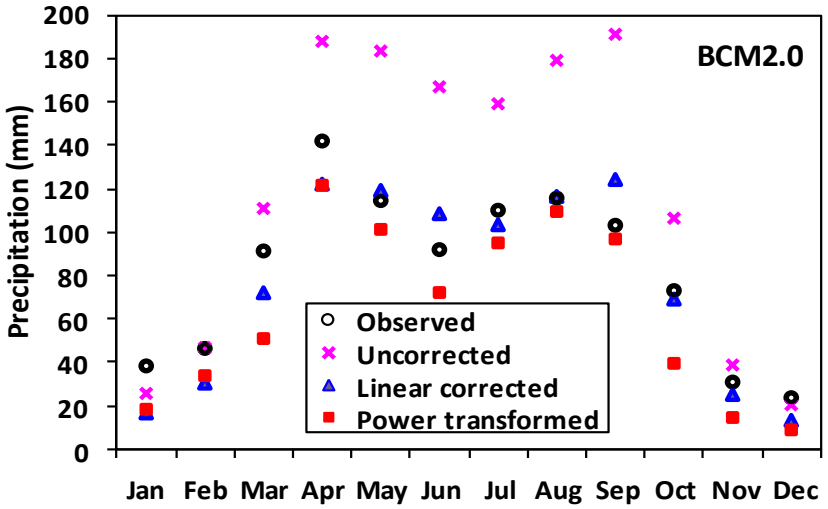
Current climate Precip. (Predicted, Observed, Bias corrected

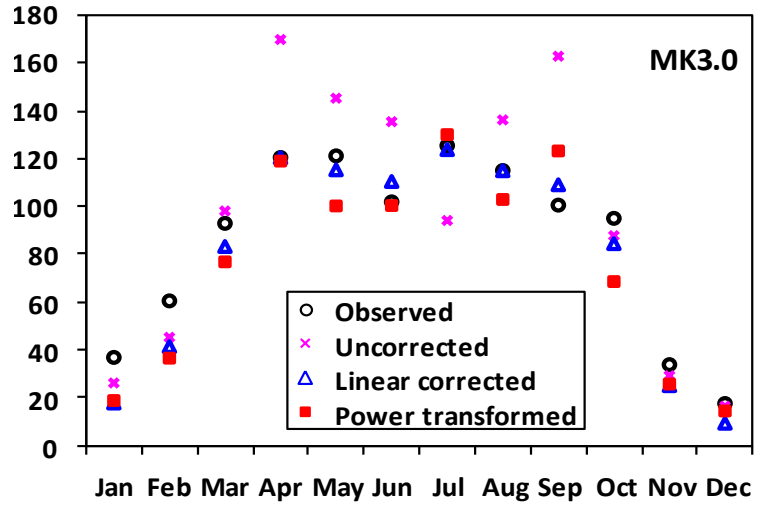




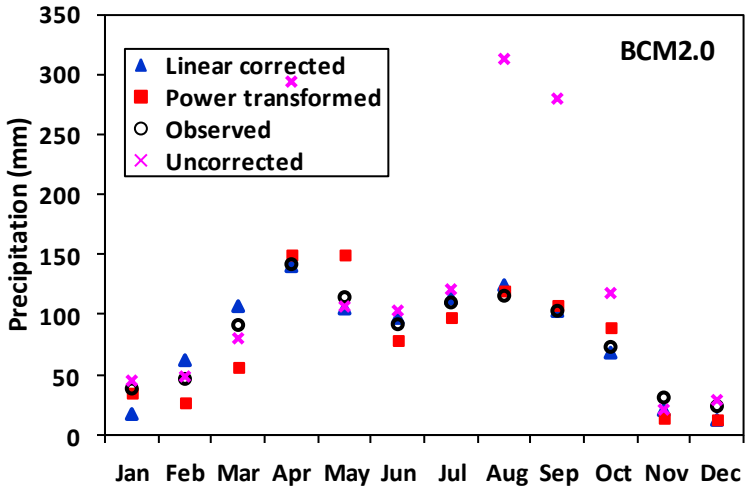
Future climate Precip. (Predicted, Observed, Bias corrected

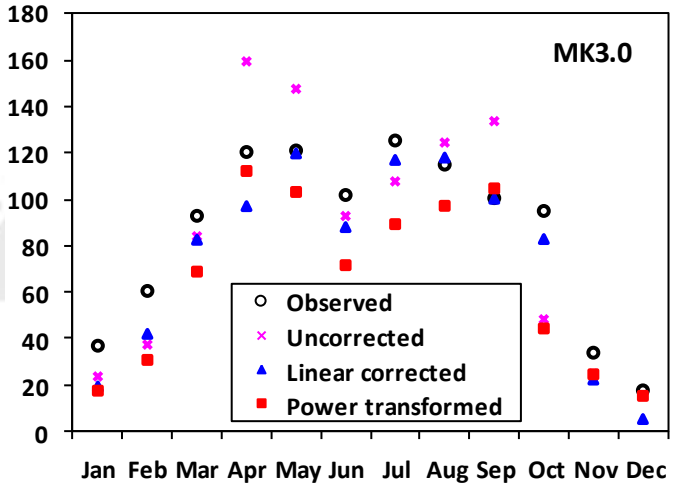
A1B scenario Precip.





A2 scenario Precip.



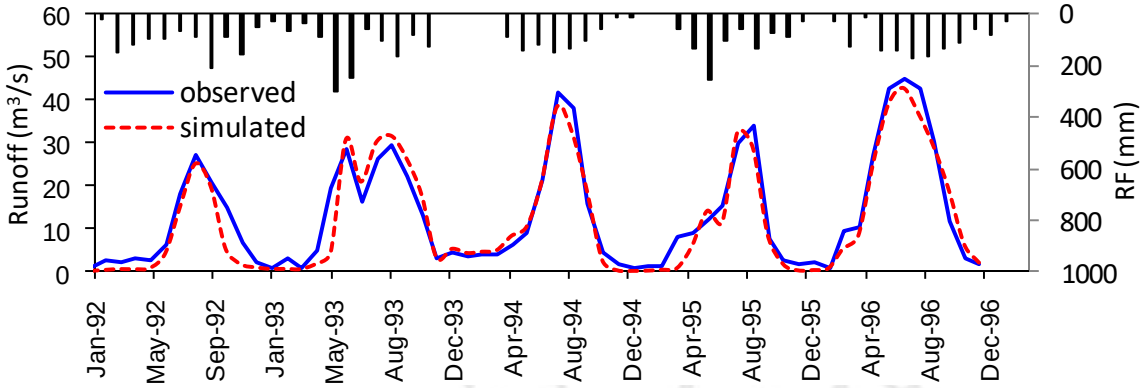


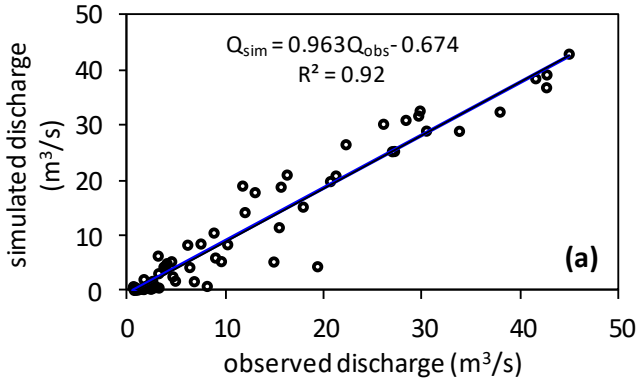
Hydrologic Modelling

- SWAT model is calibrated and validated for observed data at both watersheds.
- Runoff is simulated for current climate and future scenarios at two watersheds.
- Simulated daily runoff is aggregated to monthly series for further analysis.

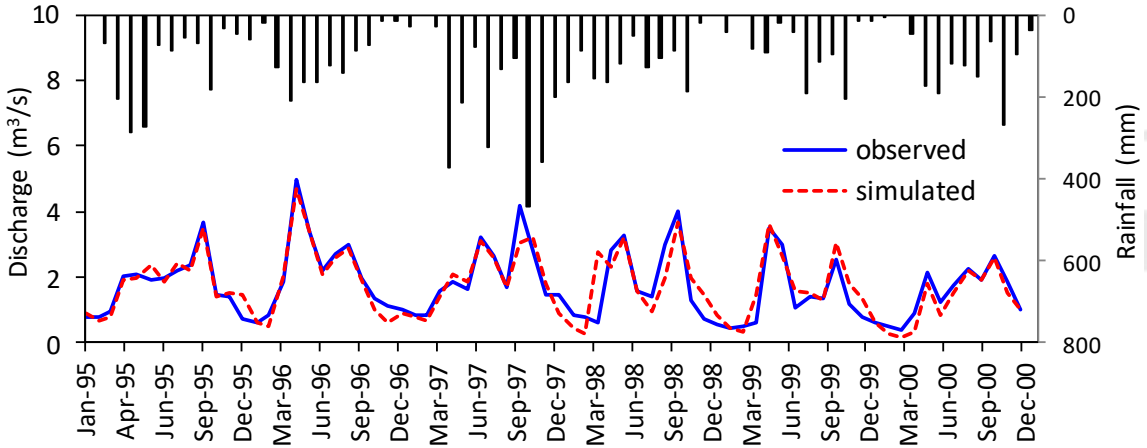
Model Calibration

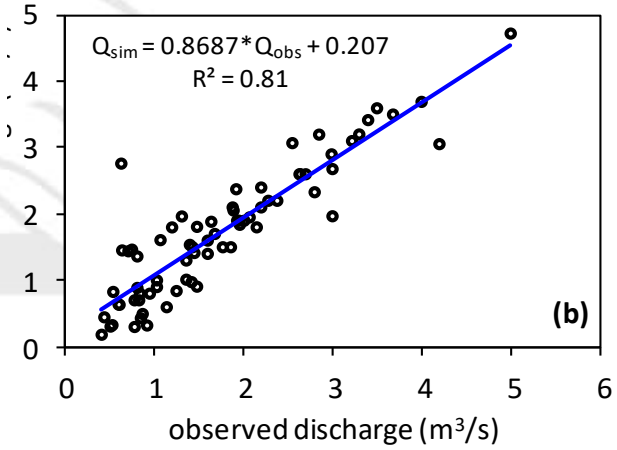
Bilate 1992-96





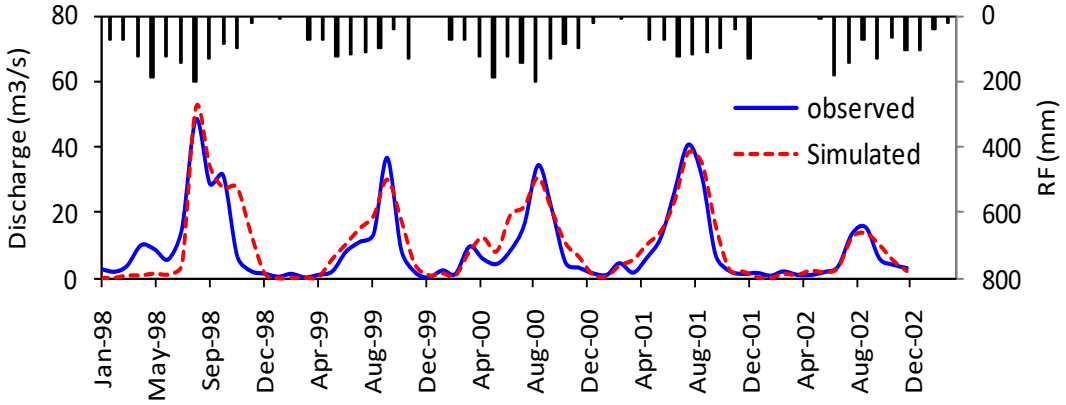
Hare 1995-00

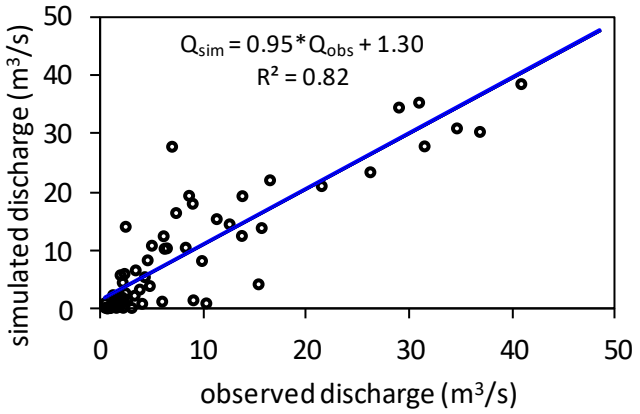




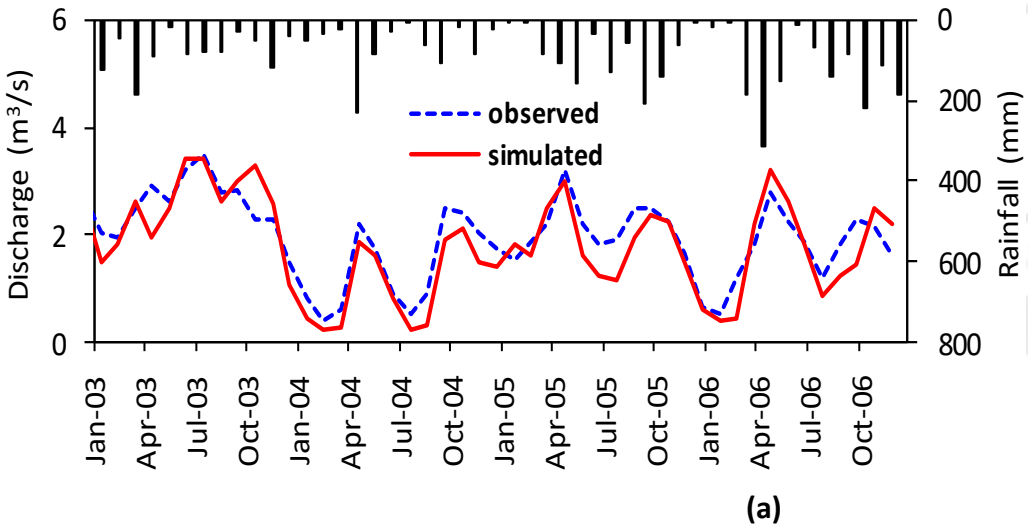
Model Validation

Bialte Watershed 1998-02

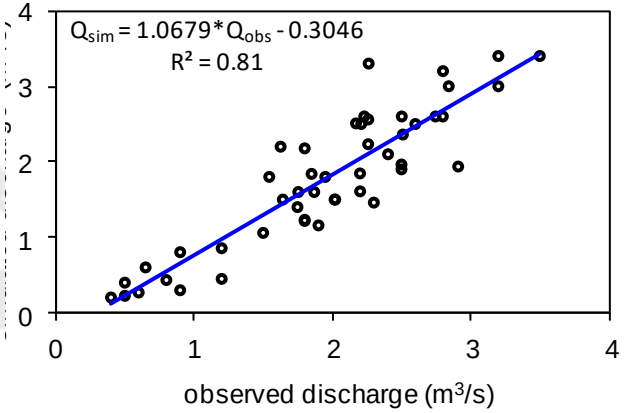




Hare Watershed 2003-06



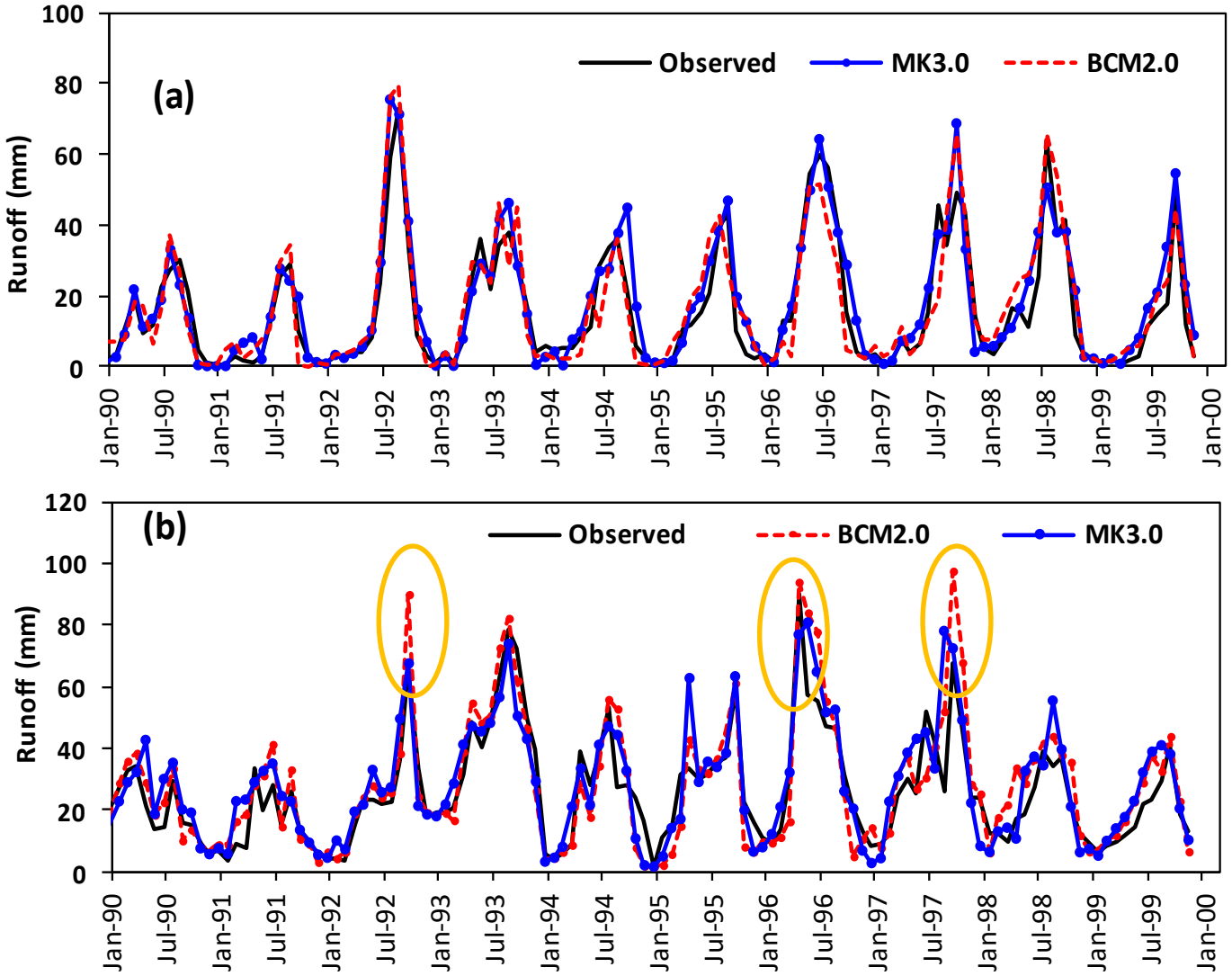
(a)



Model performance indices

Model efficiency indices	Bilate basin		Hare-basin	
	Calibration (1995-2000)	Validation (2003-2006)	Calibration (1994-2000)	Validation (2003-2006)
R^2	0.92	0.82	0.88	0.81
bR^2	0.89	0.78	0.71	0.86
NSE	0.91	0.79	0.87	0.96
PBIAS	8.93	-9.05	1.36	8.83
RSR	0.09	0.21	0.19	0.32
p-factor	0.82	0.78	0.81	0.78
r-factor	0.72	0.88	1.40	1.80

Runoff Simulated – Current climate condition (1990-99)

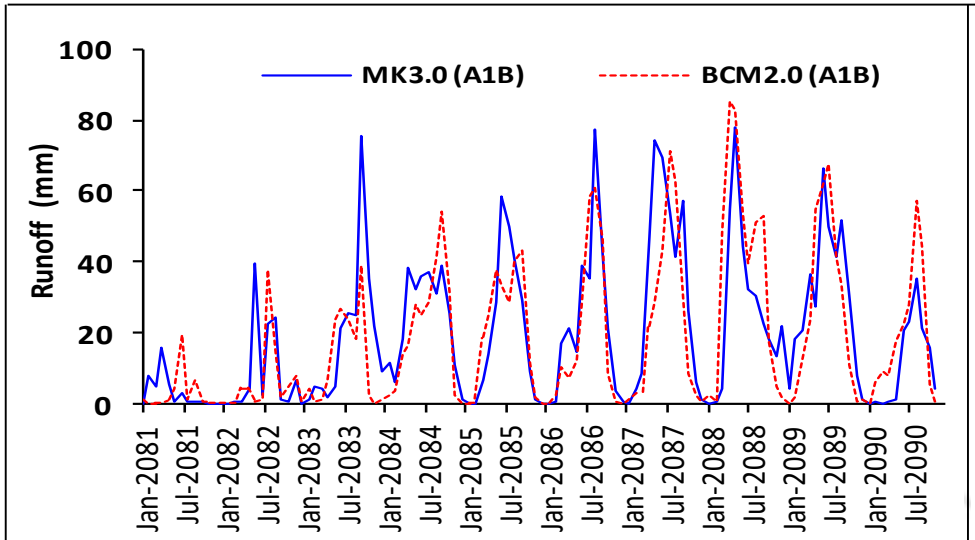


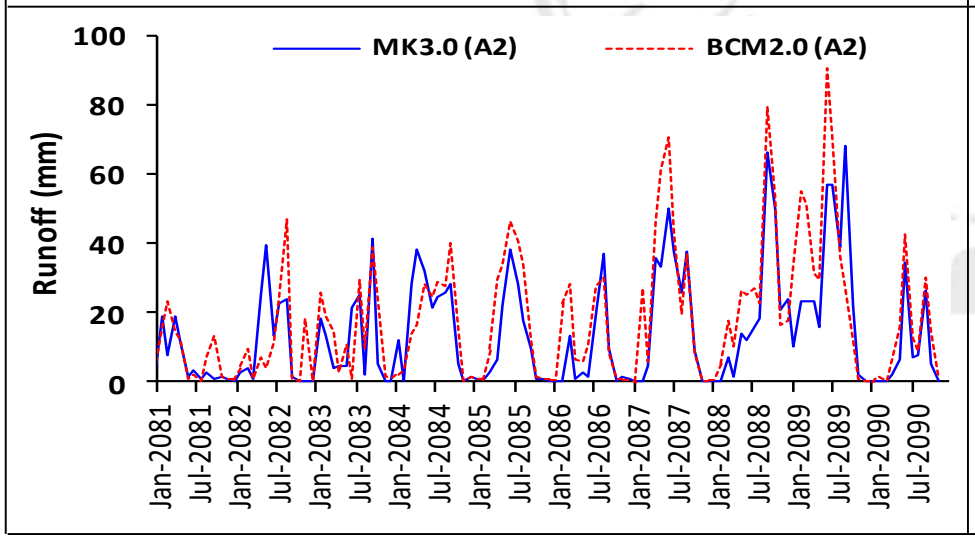
Bilate

Hare

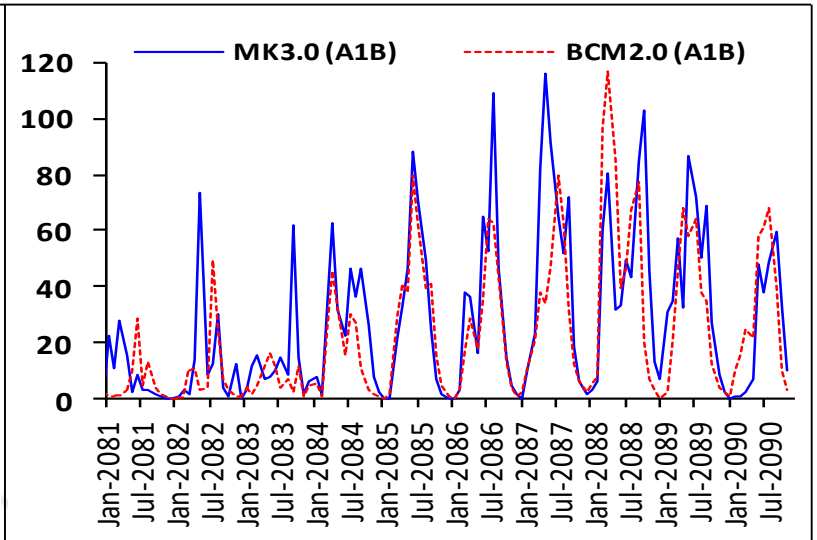
Runoff Simulated – Future climate condition (2081-90)

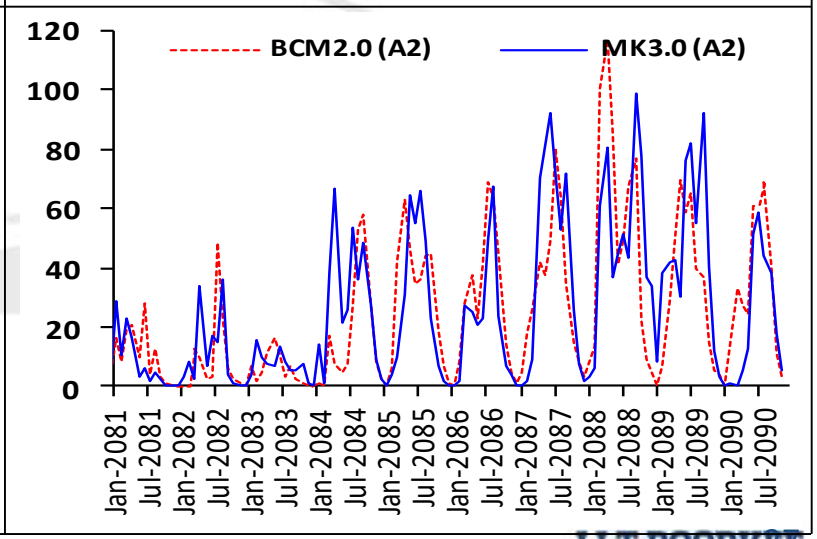
Bilate





Hare

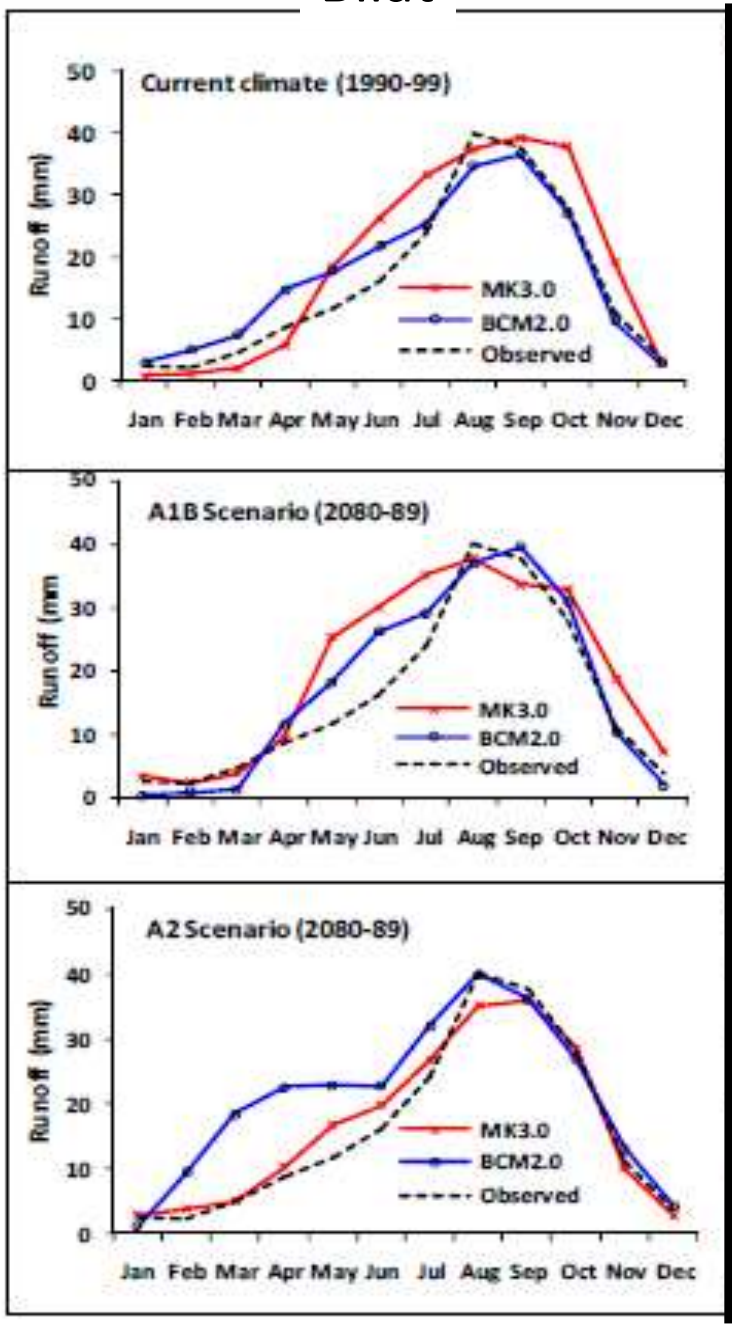


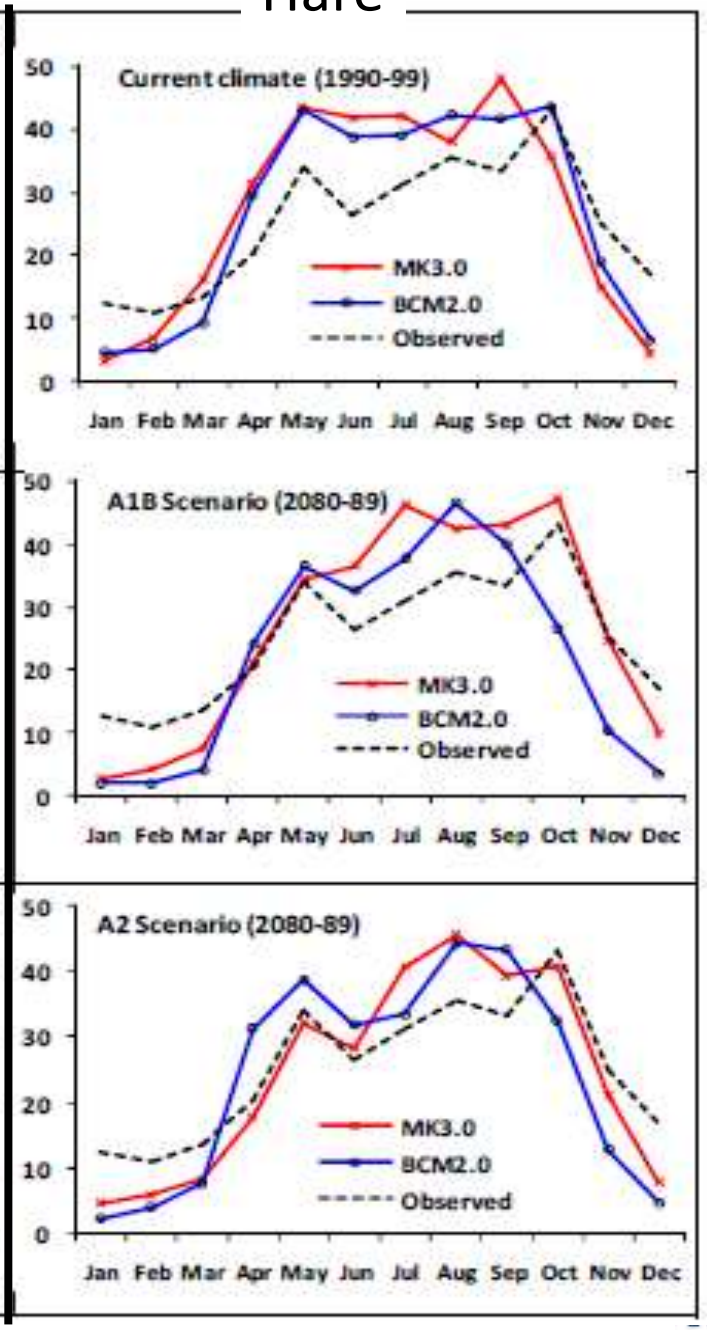


Bilat

Hare

Average monthly Runoff Simulated





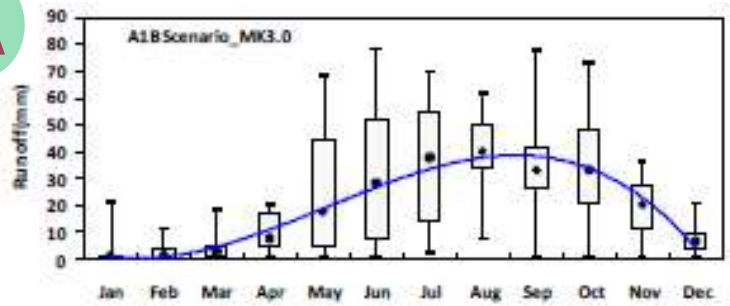
Current climate

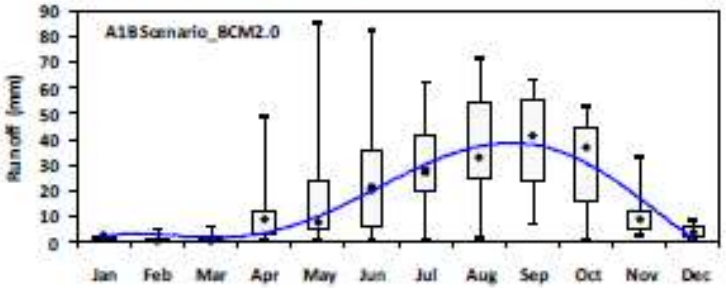
A1B scenario

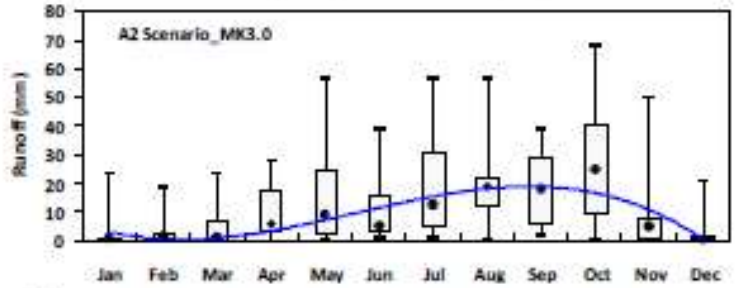
A2 scenario

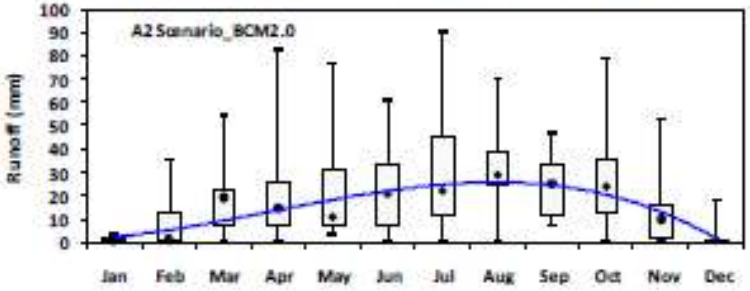
Box plots of simulated Runoff (mm)

A

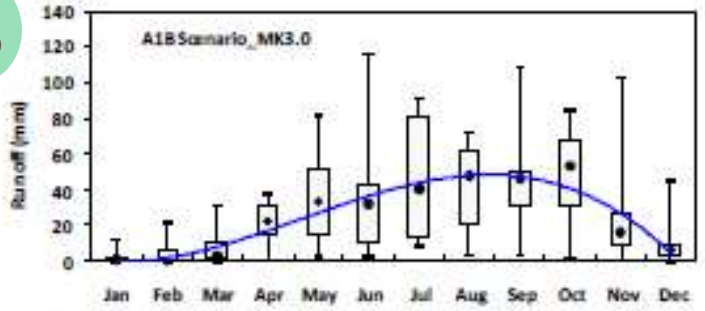


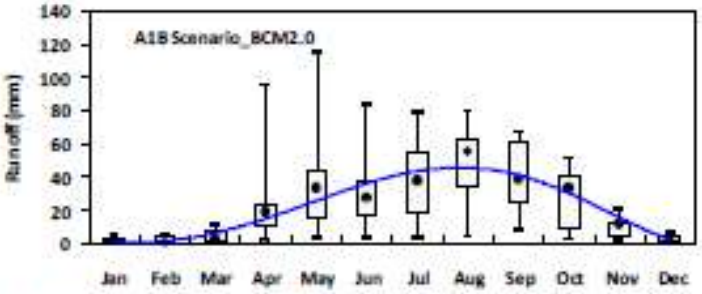


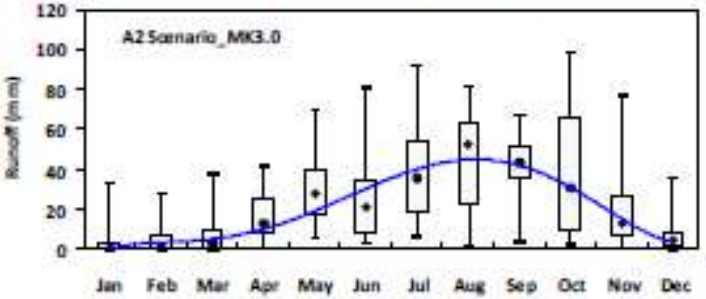


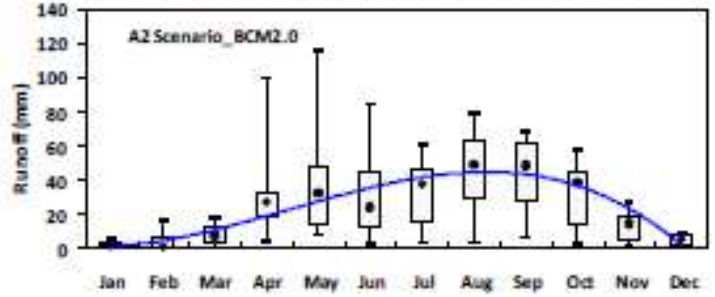


B









Conclusion

- Runoff simulated for the current climate (1990-1999) using bias corrected precipitation and temperature modestly reproduced effects similar to that of observed weather variables at both watersheds.
- The overall NSE and coefficient of determination model performance indices ranges between 0.79 and 0.96 during calibration and validation period at both watersheds; other indices are at acceptable limit.
- The simulated annual water yield is within ±3.4% error to the observed annual stream flow volume at the same outlet.

Conclusions

- Significant amount of variability is observed in downscaled precipitation for current climate whereas the associated variability for temperature is very less.
- Increased extreme precipitation and temperature events prevail for future scenarios.
- Average dry-spell length found to increase between October and February whereas it remains stable from March – September months for both emission scenarios.
- Bias correction improved both the mean and CV to a reasonable degree

Conclusions…

- Simulated average annual water yield shows slight variation between GCMs.
- The simulated future runoff is characterized by higher number of extreme events.

Thanks