Assessing the impact of climate change scenarios on water resource in the Bhima river basin in India

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INDIA

Projected climate change depend on illustrative scenarios (storylines) of greenhouse gases emissions:

Special Report on Emission Scenarios (SRES)











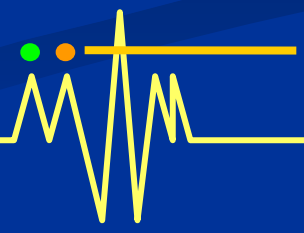


Based on different plausible pathways of future:

- development of the world
- population growth and consumption patterns
- standards and life style of living
- energy consumption & energy sources (e.g. fossil fuel usage)
- technology change
- land use change

Scope of the study

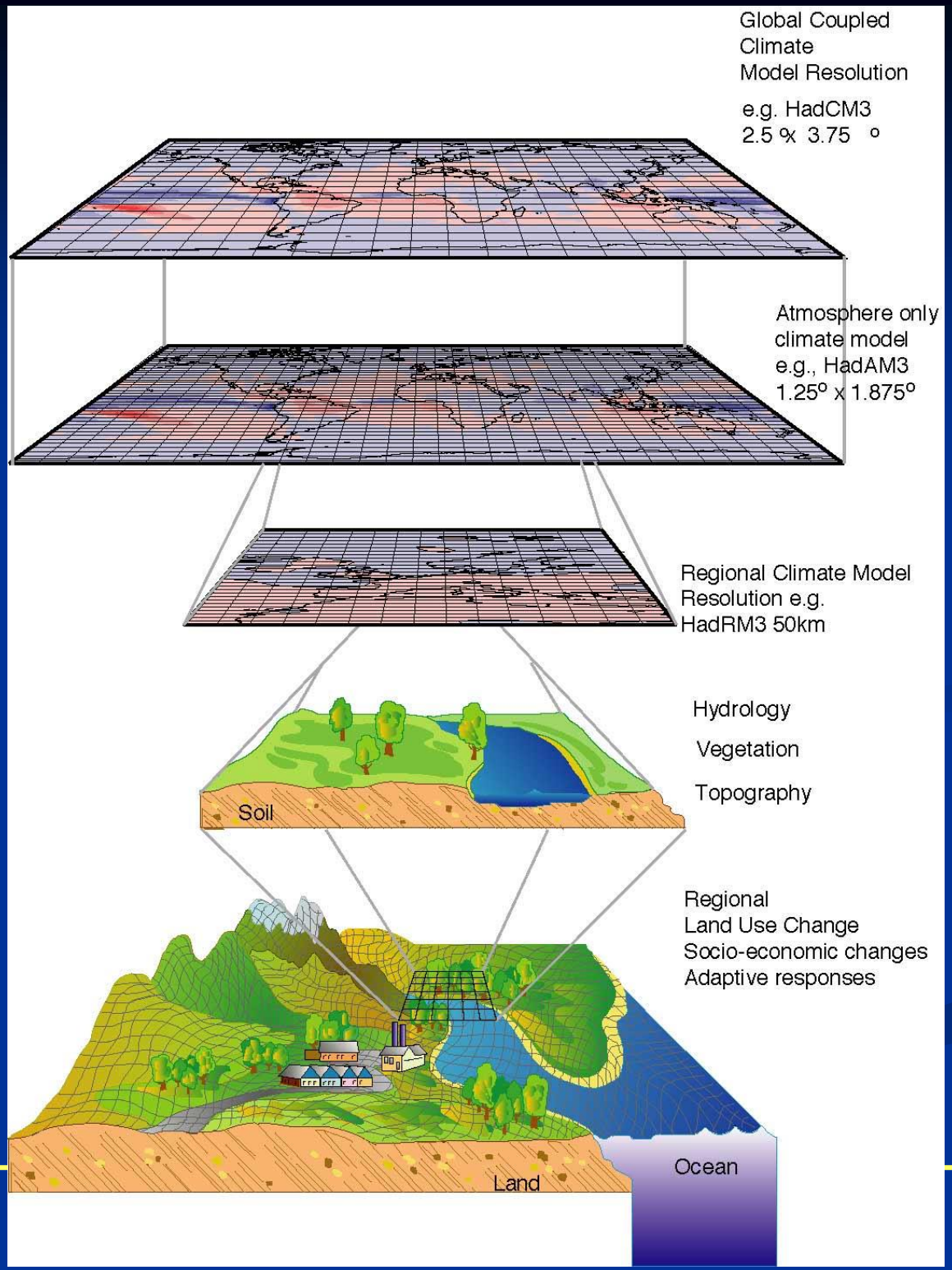
- To quantify the impact of climate change on the water resources of the Bhima river basin using hydrological model.
- PRECIS
- SWAT



GCMs to Regional Adaptive Responses : Modelling Path

Cs = f(Cl, Øs)

Cs - small scale climate
Cl - large scale climate
Øs - physiographic details at small scale



PRECIS

- **P**roviding **RE**gional **C**limates for **I**mpact **S**tudies
- High-resolution limited area model driven at its lateral and sea-surface boundaries by output from HadCM
- PRECIS runs on Linux PC (horizontal resolutions: 50 x 50 & 25 x 25 km).
- Needs data for the selected domain on lateral boundary conditions (LBC) from the driving GCM (e.g., HadCM3/ HadAM3) and the associated ancillary files (e.g., sea surface temp, vegetation, topography, etc).
- Hadley Centre, UK has been providing PRECIS as well as the driving data to several regional groups.
- Baseline (1961-90), A1B scenarios (2071-2100). Reanalysis-driven runs provide comprehensive regional data sets representing current conditions, which can assist model evaluation as well as assessment of vulnerability to current climate variability.
- Ensembles to estimate model-related uncertainties.

PRECIS Runs at IITM

(Resolution: 50km)

- LBCs derived from HadAMH. HadCM3 provided SST as boundary conditions for HadAMH.
- PRECIS runs on Linux PC (horizontal resolutions: 0.44° x 0.44°)
- The LBCs have a length of 138 years, and are available for Baseline (1961-90), A1B scenario (1961-2098), with the sulphur cycle.
- The basic parameters analyzed are the mean surface (1.5 m) temp and total precip.
- The precip & temp obs data ,IMD Grided precipitation and (CRU20, 1961-90) temperature is used to validate model performance in simulating current climate.
- The analysis comprised of both annual mean and seasonal mean for DJF, MAM, JJA and SON.
- Continuous simulations of provide an opportunity to assess the impact of climate change on the Indian monsoon for three time slices representing the near, medium and long-term with implications for policy on these timescales.

Model-simulated monsoon rainfall and its variability

- The high-resolution regional simulations generated using PRECIS with LBC from QUMP simulations-evaluate the model skills in representing the regional climatological features , especially summer monsoon characteristics
- Three simulations, viz. Q0, Q1 and Q14 have been used,
- Q0 and Q14 have shown good skill in their ability to simulate the quantum of seasonal rainfall (879 and 865 mm respectively, where as Q1 shows a dry bias (637mm)
- Variability, Q1 (71 mm), Q0 (53 mm)and Q14 (66 mm)
- Hence Q0 simulation has been used for further analysis.

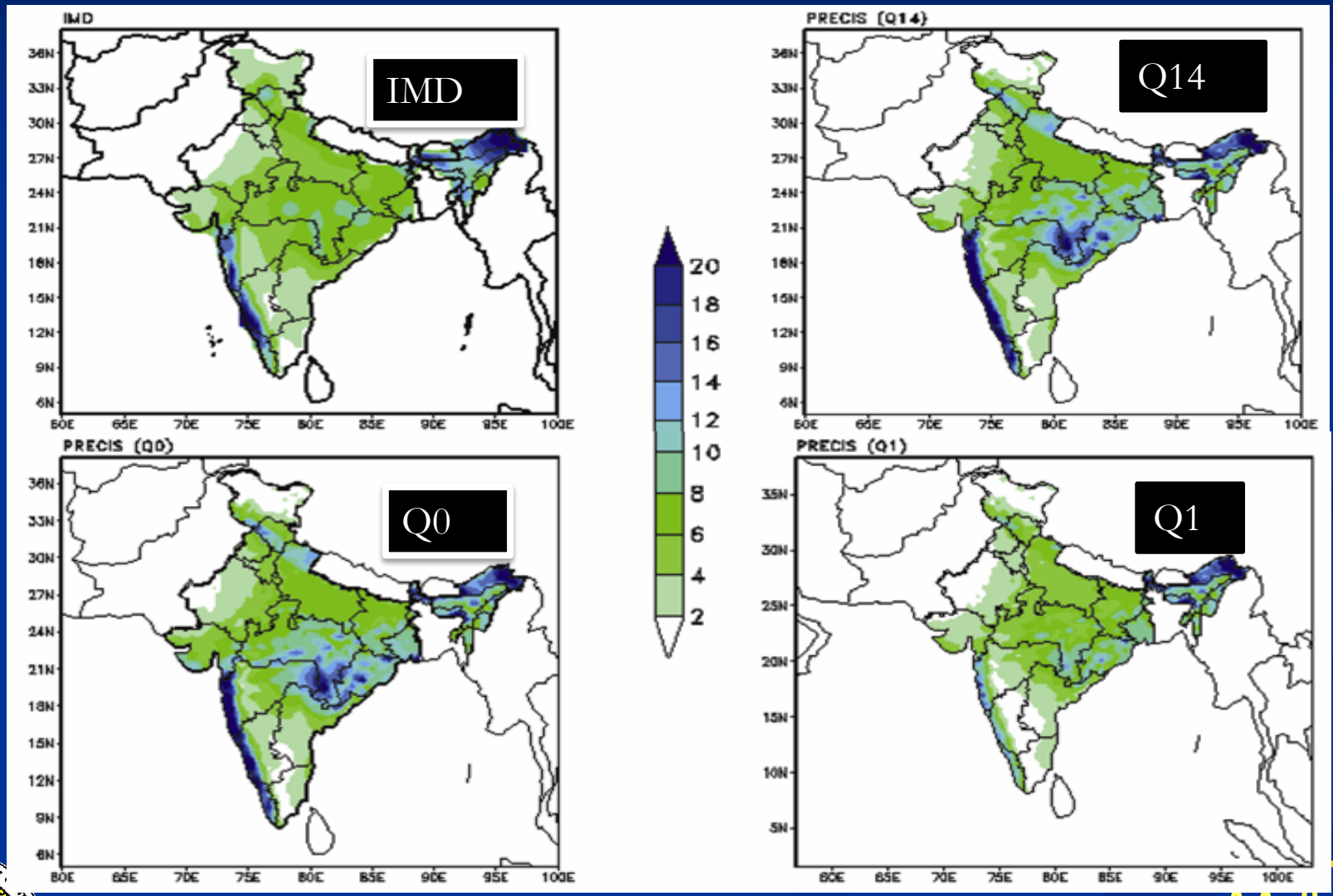
Characteristics of simulated seasonal and annual rainfall (mm) for all-India (baseline and A1B scenarios-Q0 simulation as simulated of PRECIS (Krishna Kumar et.al 2011)

Q0 (mean)	JF	MAM	JJAS	OND	Annual
Obs	27	120	954	132	1234
1970s	41	229	879	126	1275
2020s	37	219	911	136	1303
2050s	51	243	980	146	1421
2080s	51	243	1024	153	1471
Standard	Deviation				
Obs	10.3	23.3	97.3	28.8	114.7
1970s	**18.1**	50.6	53.0	27.1	74.0
2020s	22.2	49.0	54.8	41.2	79.9
2050s	34.2	63.9	67.8	50.4	102.7
2080s	25.7	69.0	60.9	43.4	101.4

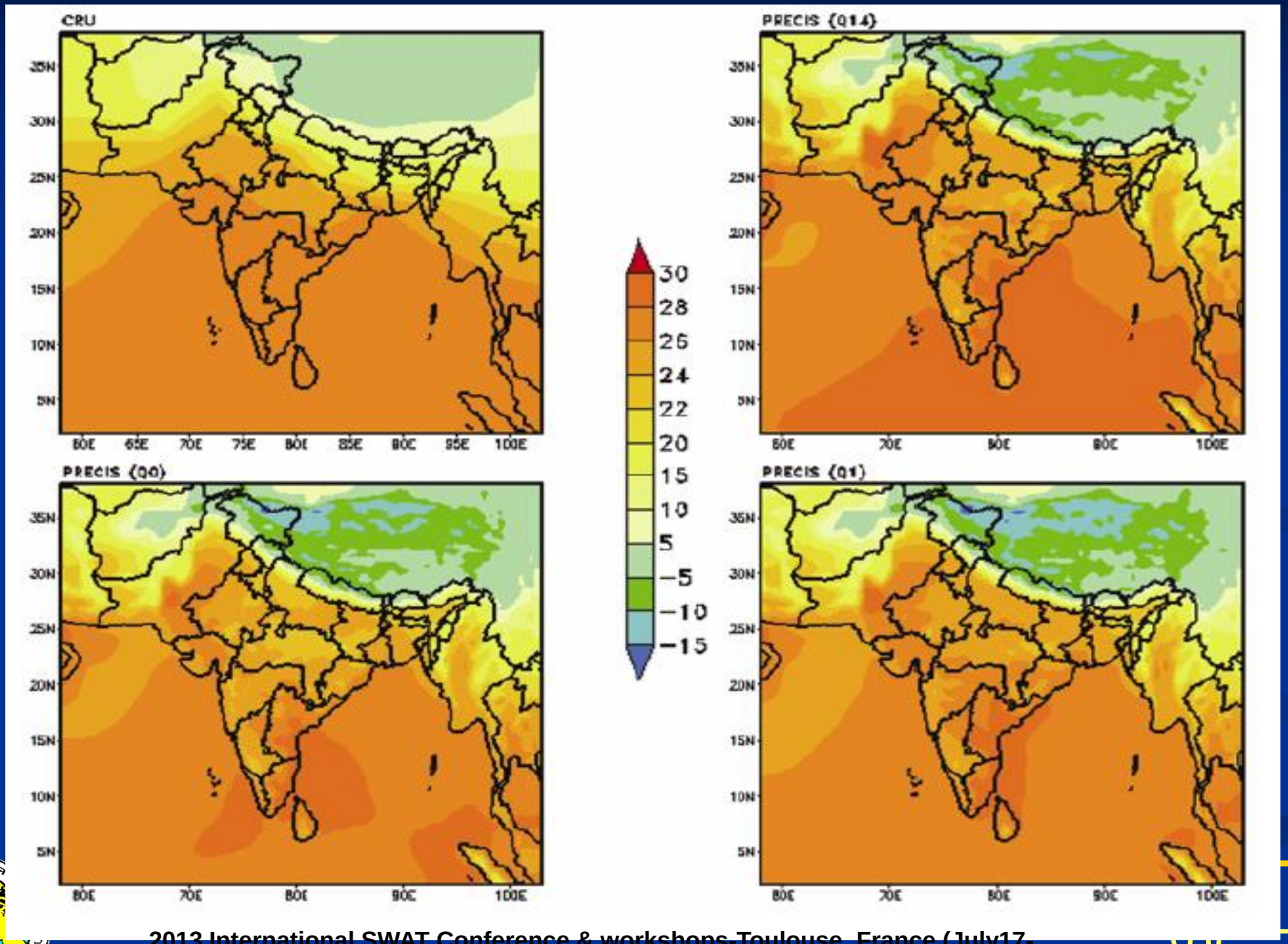
Characteristics of simulated seasonal mean temperature (° C) for all-India (baseline and A1B scenarios-Q0 simulation as simulated of PRECIS (Krishna Kumar et.al 2011)

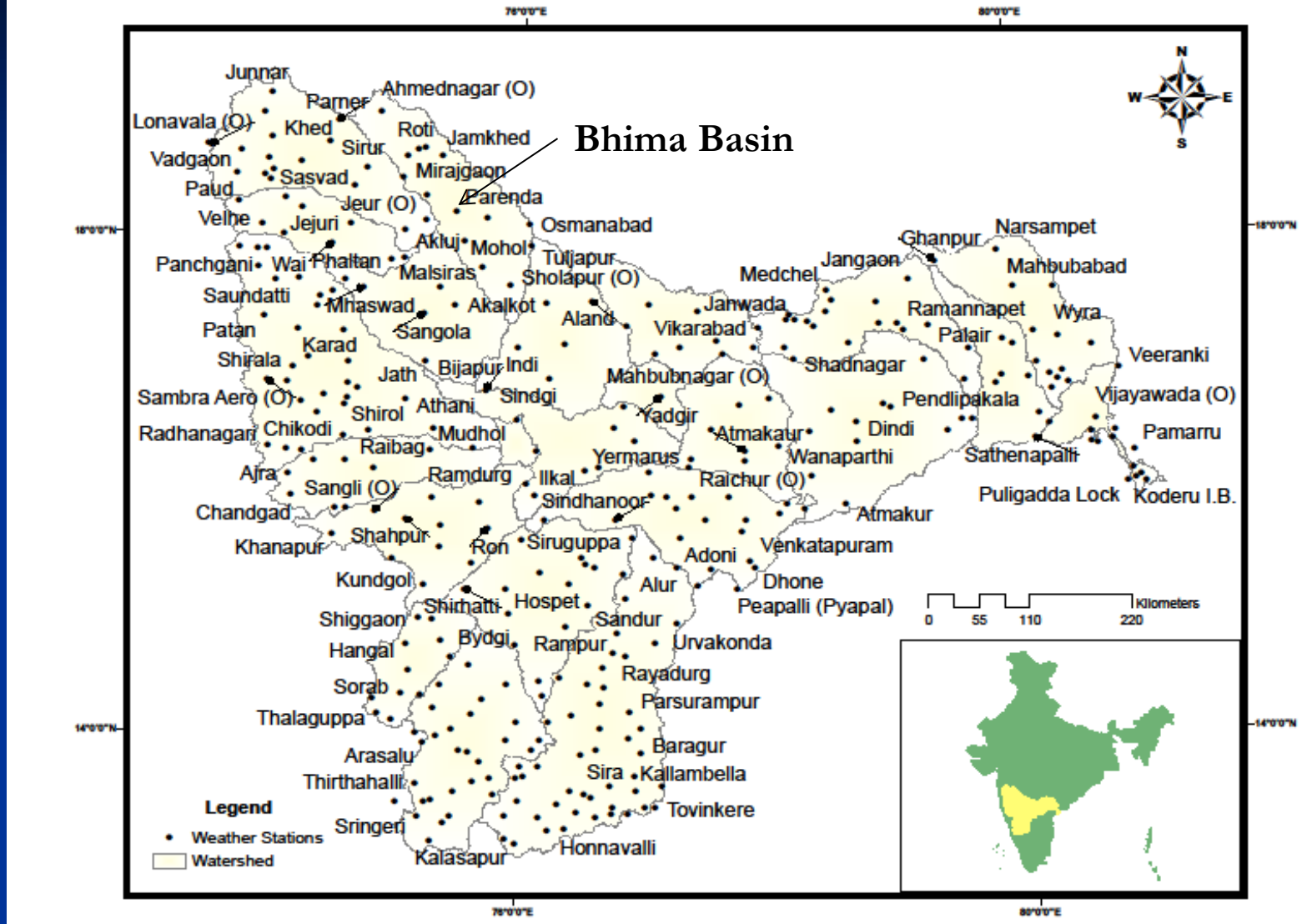
Q0 (mean)	JF	MAM	JJAS	OND	Annual
Obs	18.2	26.9	27.5	21.3	24.3
1970s	14.7	26.5	24.8	24.8	21.5
2020s	16.5	28.0	26.2	26.2	23.1
2050s	18.2	29.4	27.1	27.1	24.4
2080s	19.3	30.6	28.3	28.3	25.6
Standard	Deviation				
Obs	0.5	0.5	0.3	0.3	0.2
1970s	**1.1**	0.7	0.6	0.6	0.4
2020s	0.9	0.9	0.8	0.8	0.6
2050s	1.2	0.9	0.8	0.8	0.6
2080s	1.0	0.7	0.6	0.6	0.4

Spatial patterns of summer monsoon rainfall climatology as simulated in the three simulations of PRECIS (Q0, Q1 and Q14). The observed monsoon rainfall climatology (Obs) is based on the gridded IMD rainfall data. The climatologies correspond to the period 1961–1990.

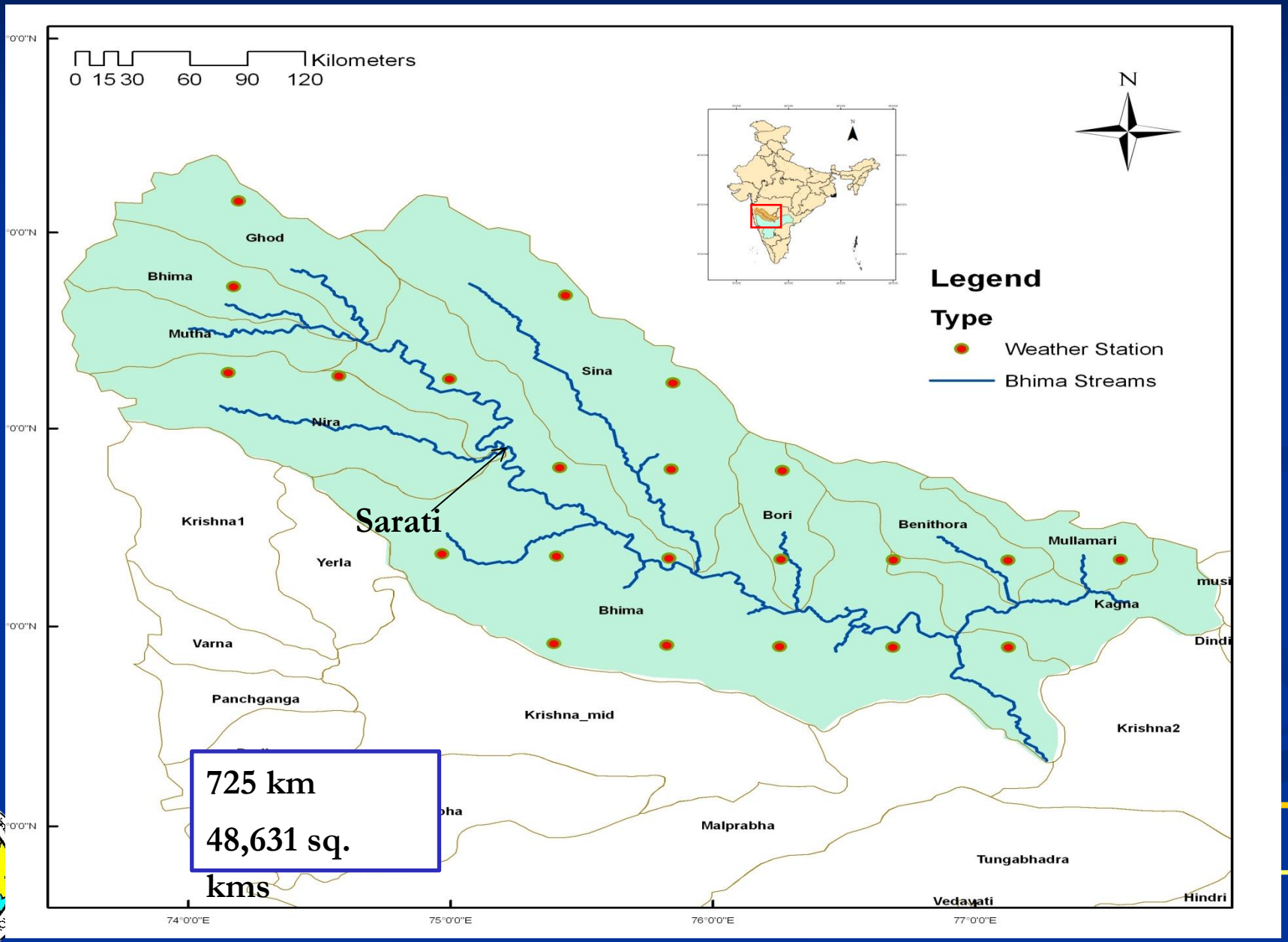


Simulated annual surface air temperature by PRECIS withCRU temperature data (1961-1990)




Bhima Basin
Junnar
Parner
Ahmednagar (O)
Lonavala (O)
Khed
Roti
Jamkhed
Sirur
Vadgaon
Mirajgaon
Sasvad
Paud
Parenda
Jeur (O)
Velhe
Jejuri
Osmanabad
Akluj
Mohol
Tuljapur
Panchgani
Wai
Phaltan
Malsiras
Sholapur (O)
Saundatti
Mhaswad
Akalkot
Aland
Patan
Sangola
Karad
Shirala
Jath
Bijapur
Indi
Sambra Aero (O)
Sindgi
Athani
Shirol
Radhanagari
Chikodi
Mudhol
Raibag
Ajra
Ramdurg
Ilkal
Sangli (O)
Chandgad
Sindhanoor
Khanapur
Shahpur
Ron
Siruguppa
Kundgol
Shiggaon
Shirhatti
Hospet
Hangal
Bydgi
Rampur
Sorab
Thalaguppa
Arasalu
Thirthahalli
Sringeri
Kalasapur
Honnavalli
Sira
Kallambella
Tovinkere
Baragur
Parsurampur
Rayadurg
Urvakonda
Alur
Sandur
Adoni
Dhone
Peapalli (Pyapal)
Venkatapuram
Atmakur
Raichur (O)
Yermarus
Yadgir
Mahbubnagar (O)
Vikarabad
Janwada
Medchel
Jangaon
Ghanpur
Narsampet
Mahbubabad
Ramannapet
Wyra
Palair
Shadnagar
Veeranki
Pendlipakala
Vijayawada (O)
Dindi
Pamarru
Atmakur
Wanaparthi
Sathenapalli
Puligadda Lock
Koderu I.B.
N
S
E
W
Kilometers
0
55
110
220
Legend
Weather Stations
Watershed
18°0'0"N
14°0'0"N
76°0'0"E
80°0'0"E

Bhima river basin



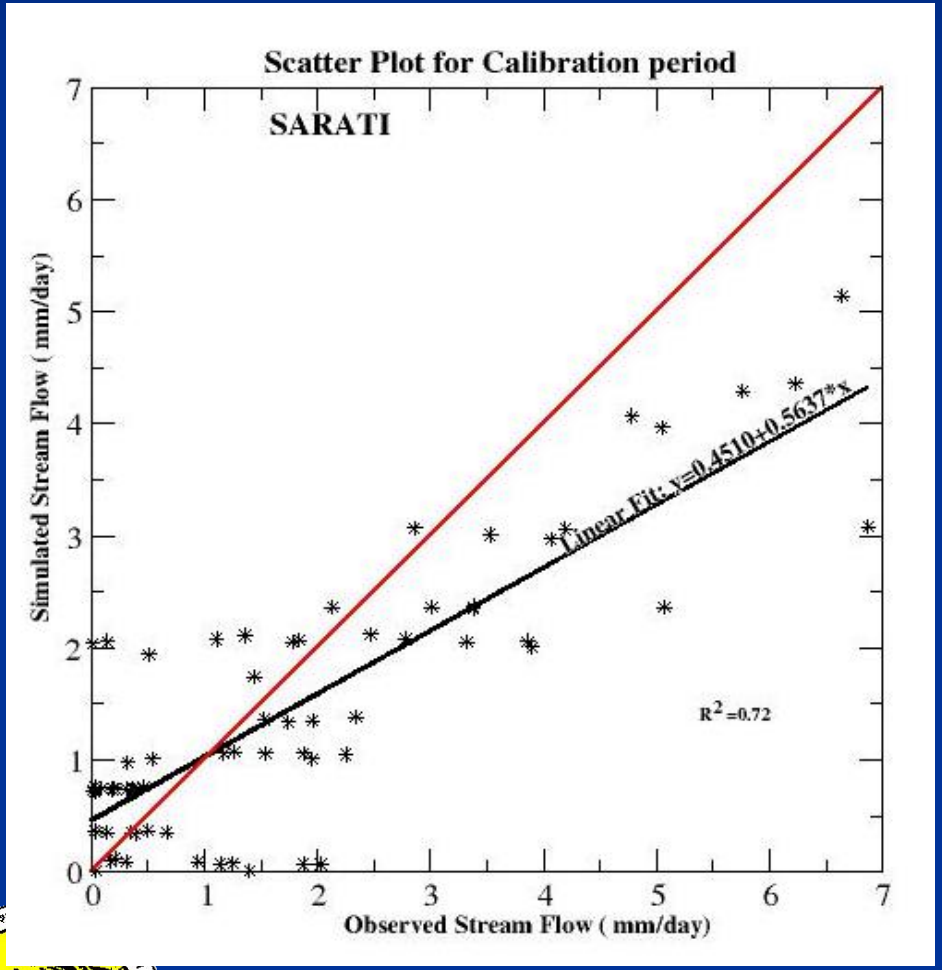
Rainfall Climatology of the Bhima Basin

Months / Seasons	Mean Rainfall (cm)	Rainfall as % of annual	Standard Deviation	C.V. (%)
January	0.30	0.4	0.95	328
February	0.21	0.3	0.67	365
March	0.38	0.5	0.95	267
April	1.24	1.5	1.85	161
May	2.89	3.5	3.65	132
June	12.49	15.3	7.92	64
July	20.05	24.5	11.06	65
August	15.54	19.0	9.89	77
September	17.23	21.1	10.95	64
October	8.17	10.0	7.46	91
November	2.81	3.4	4.54	161
December	0.57	0.7	1.50	270
Winter (Jan.-Feb.)	0.51	0.6	1.21	253
Pre-monsoon (Mar.-May)	4.46	5.5	4.17	98
Monsoon (Jun.-Sept.)	65.36	79.9	22.26	34
Post-monsoon (Oct.-Dec.)	11.45	14.0	8.68	75
Annual	81.76	100.0	25.02	30

Model Calibration and validation

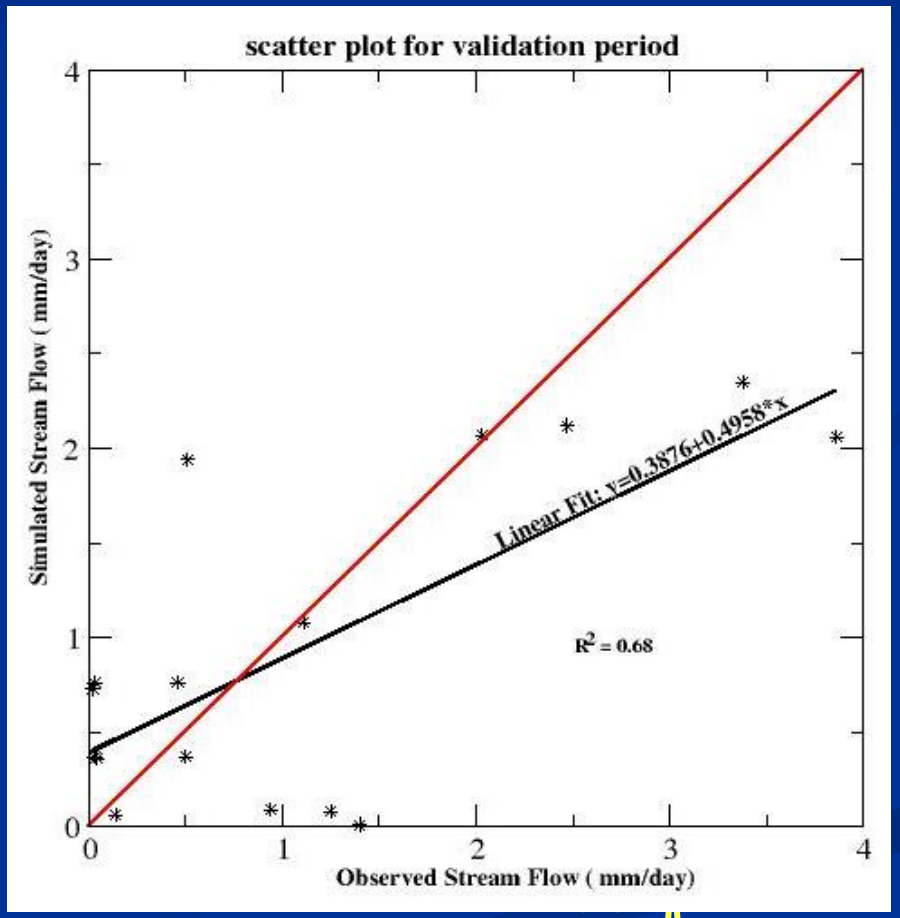
Calibration 1970-1986

R^2=0.72, NSE= 0.80

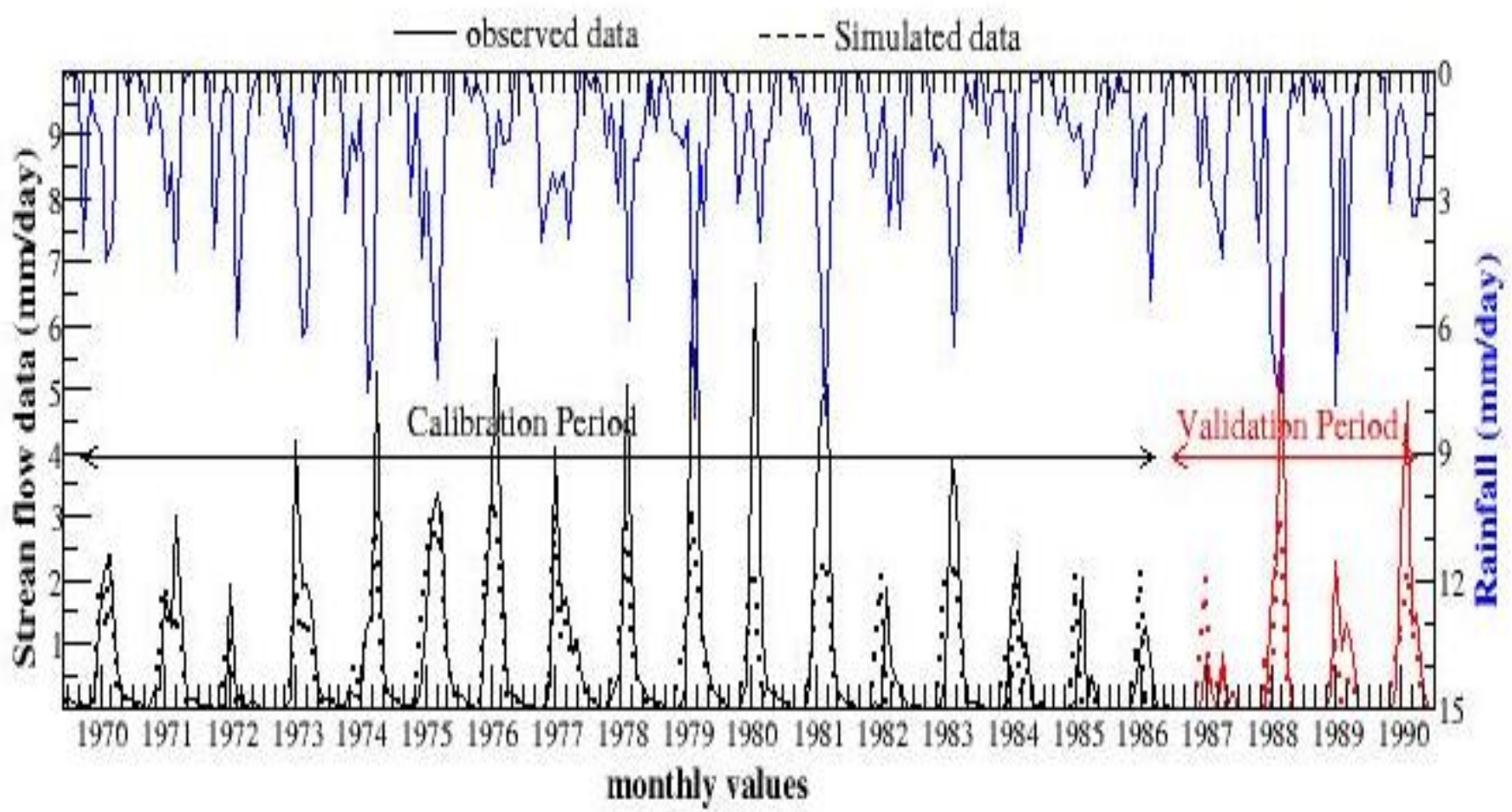


Validation 1987-1990

R^2=0.68, NSE= 0.81



Comparison between the simulated and observed monthly monsoon stream flow during calibration and validation period



DATA INPUTS FOR HYDROLOGICAL MODELING

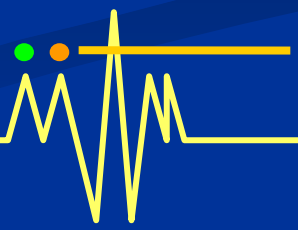
DEM

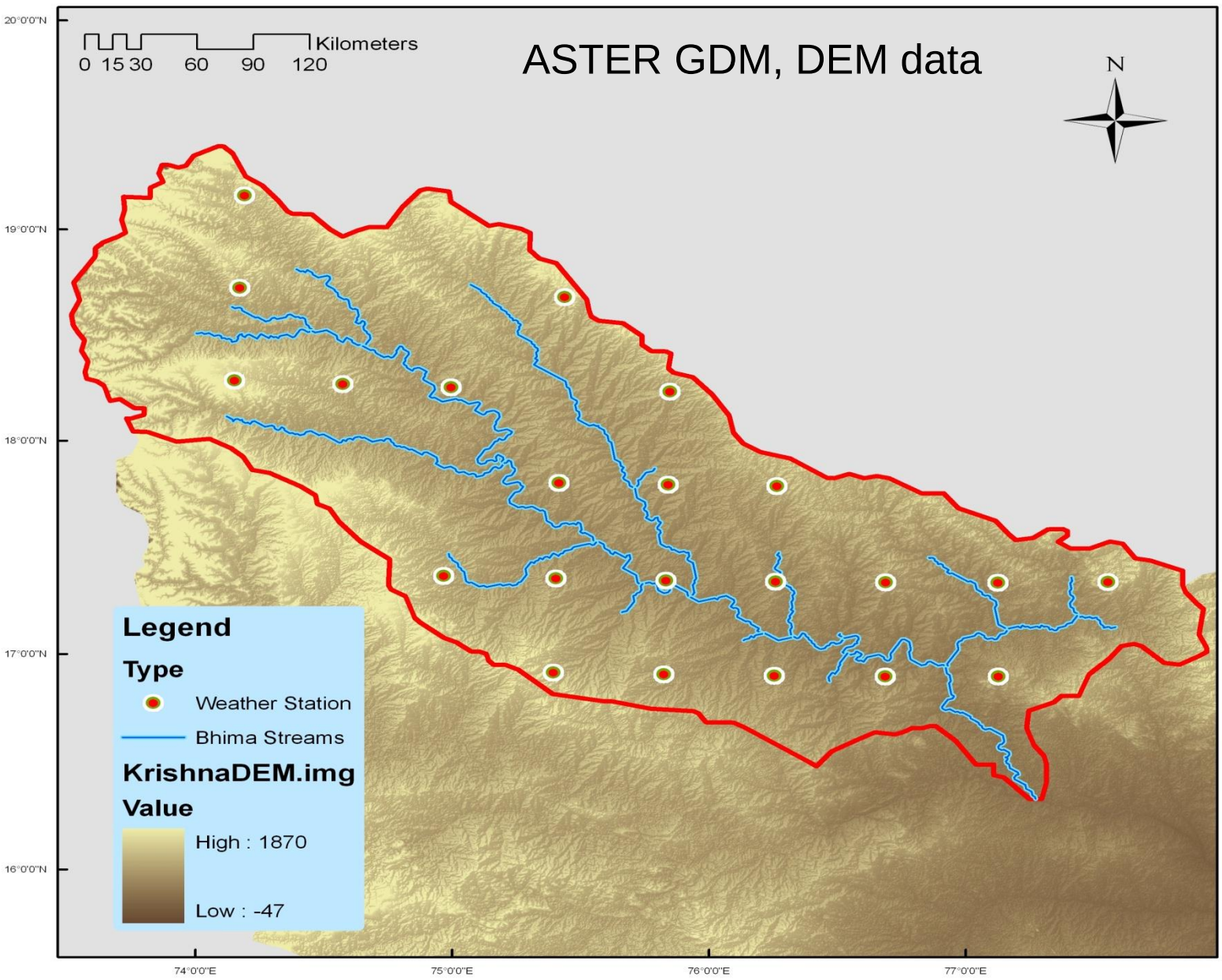
Weather Gen.

Soil

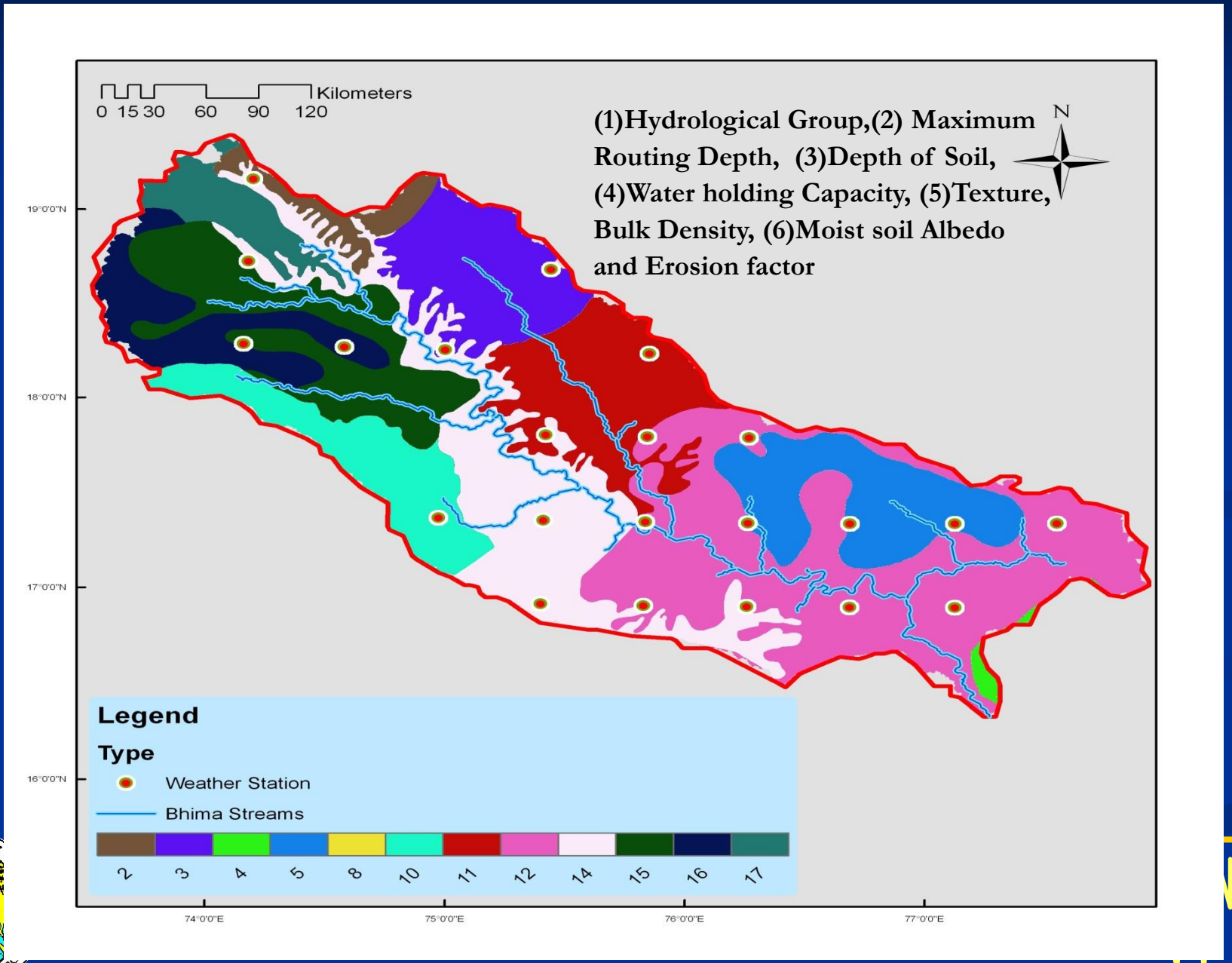
Climate Model.

Land Use

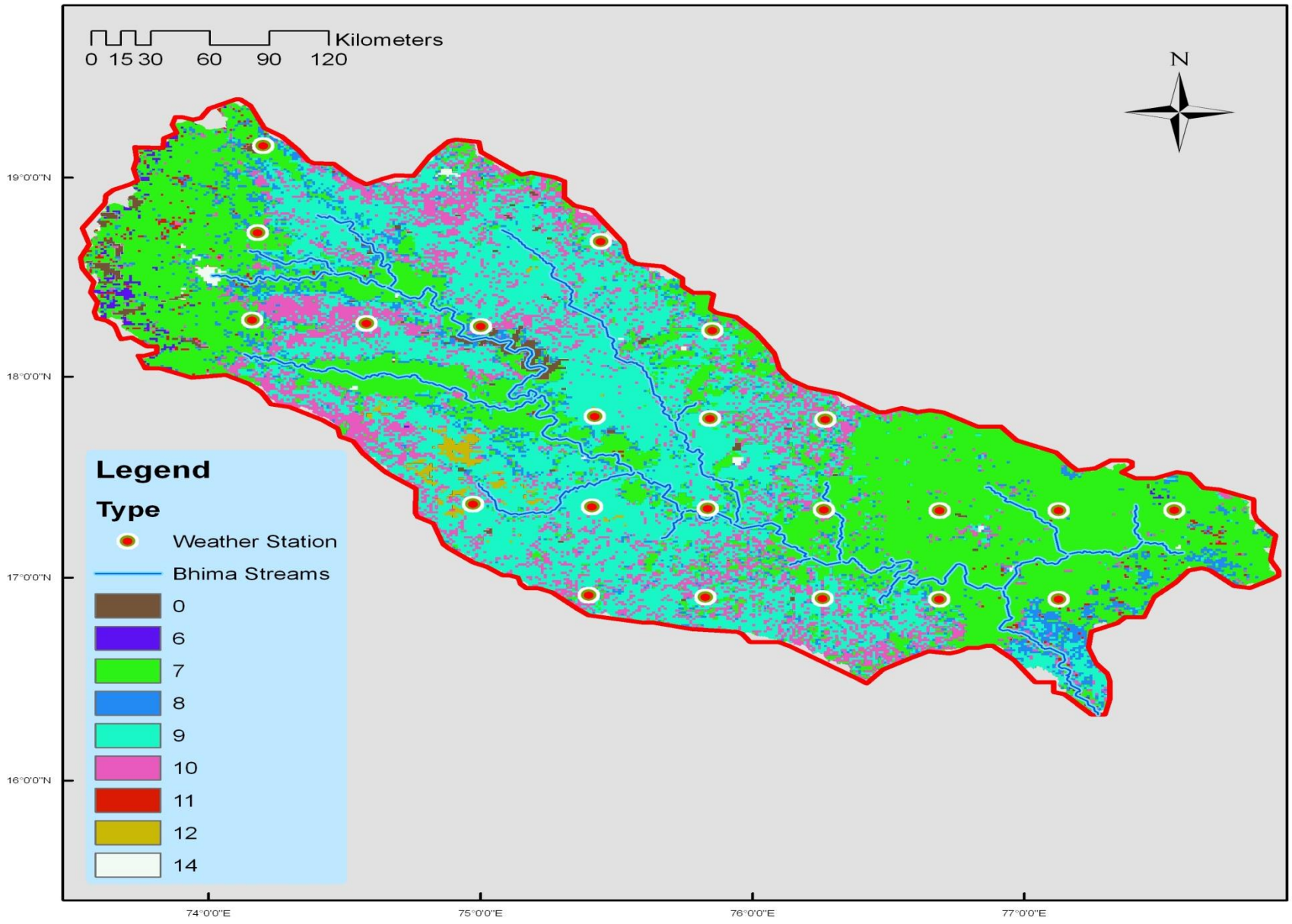



ASTER GDM, DEM data
Kilometers
0 15 30 60 90 120
N
20°0'0"N
19°0'0"N
18°0'0"N
17°0'0"N
16°0'0"N
74°0'0"E
75°0'0"E
76°0'0"E
77°0'0"E
Legend
Type
Weather Station
Bhima Streams
KrishnaDEM.img
Value
High : 1870
Low : -47

Soil Data (NBSS &LUP)

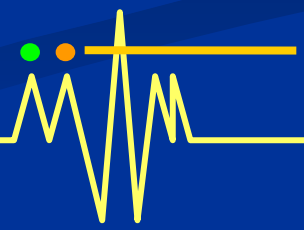


Land use and land cover layer of the Bhima basin



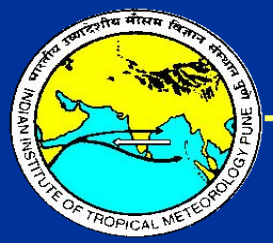
Weather Generator Data

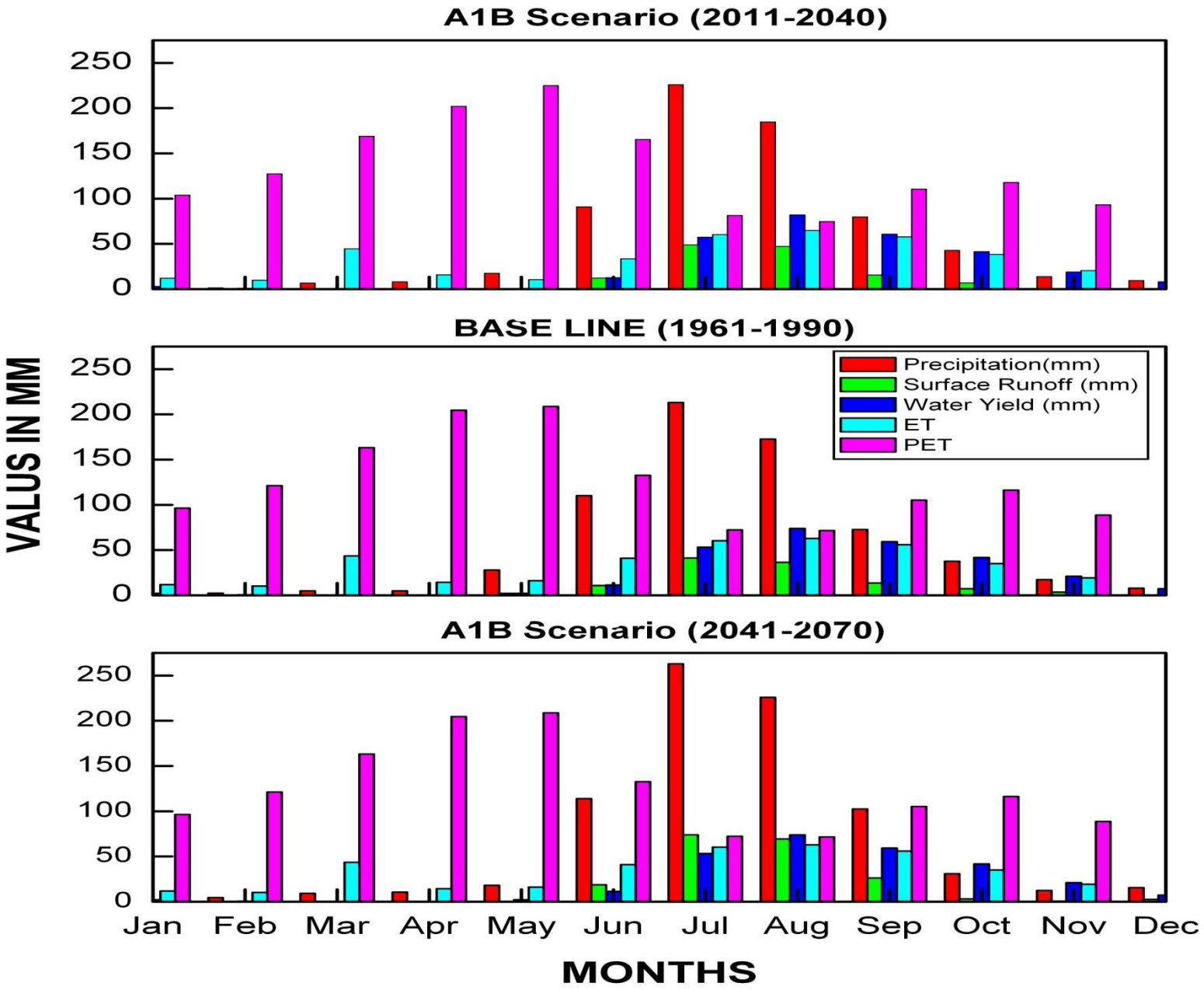
- Daily Precipitation
- Maximum and Minimum Temperature
- Solar Radiation
- Relative Humidity
- Wind speed



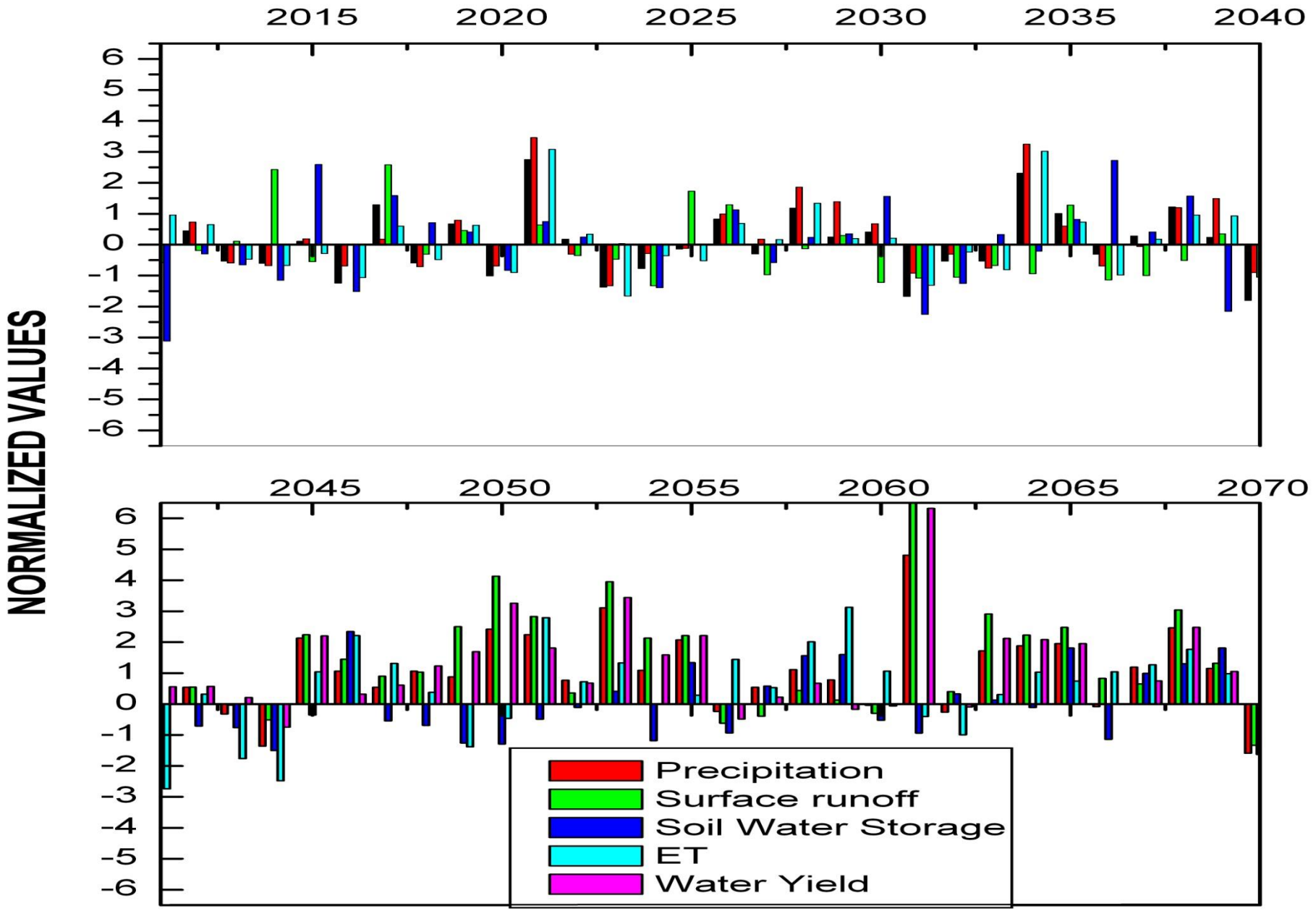
Climate Model Data

- PRECIS simulated data from IITM
- Resolution 50 km x 50 km
- Simulated daily weather data viz. precipitation, maximum and minimum temperature, solar radiation for A1B Scenarios for the period
- 1960-1990 (baseline), 2011-2040 and 2040-2070



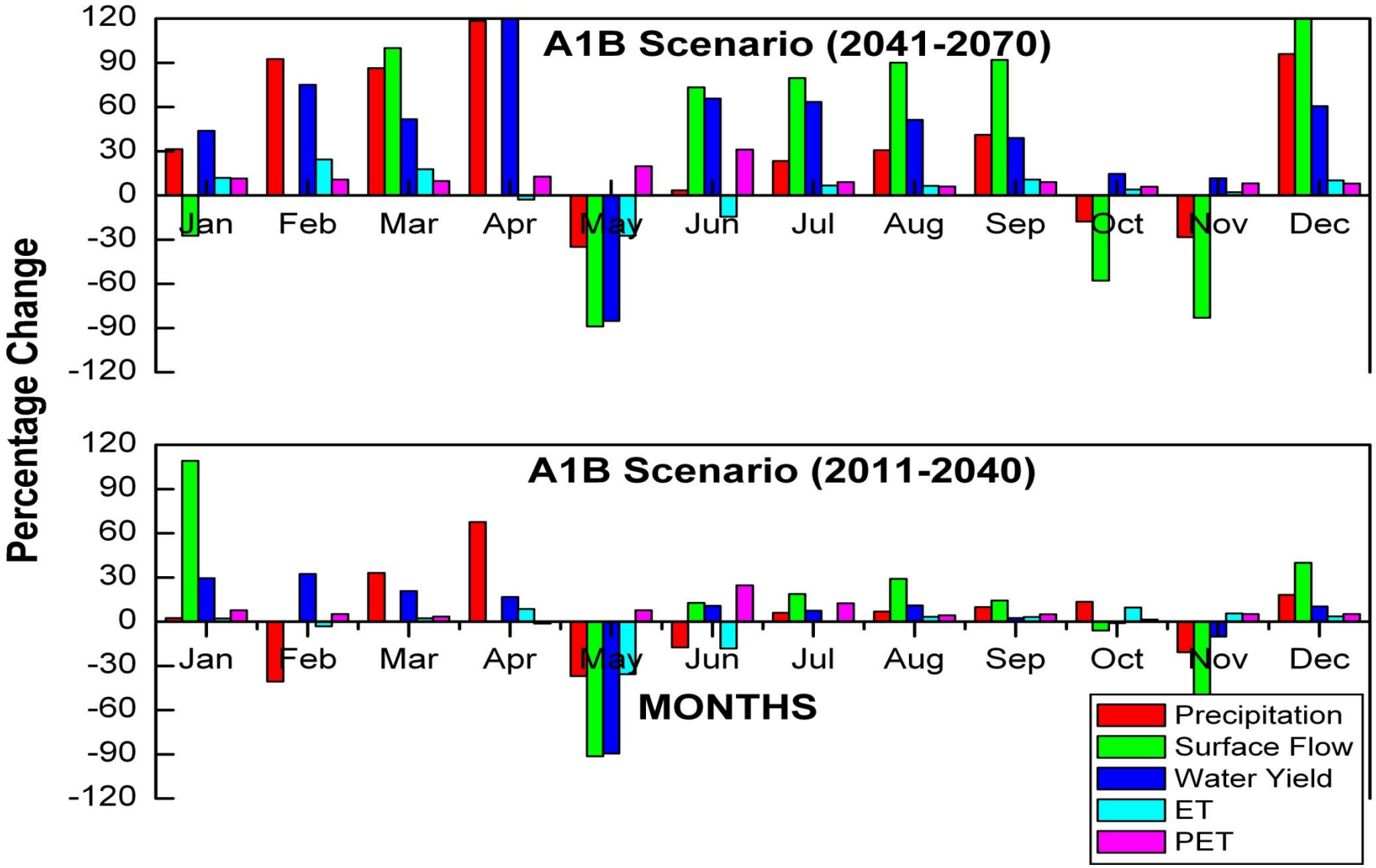


Mean monthly water balance components for control & A1B Scenarios



Mean monthly water balance components for A1B Scenarios (2011-2040 & 2041-2070)

CHANGES IN WATER BALANCE COMPONENTS



LIMITATIONS OF THE STUDY

1. It also should be noted that future flow conditions cannot be projected exactly due to uncertainty in climate change scenarios and GCM outputs.
2. Climate change impact assessment on water availability based on two model analyses and out puts, which are depends on simplified assumptions Hence, it is unquestionable that the uncertainties presented in each of the models and model outputs kept on cumulating while progressing towards the final output. These Uncertainties include: Uncertainty Linked to Data quality, General circulation Model (GCMs), Emission scenarios.
3. The model simulations considered only future climate change scenarios assuming all other things constant. But change in land use scenarios, soil, management activities and other climate variables will also contribute some impacts on water availability and crop production.

CONSULISIONS

- In this study projections of precipitation and evaporation change and their impacts on stream flow were investigated in the Bhima river basin for the 21st century. The SWAT model is well able to simulate the hydrology of the Bhima river Basin. The future annual discharge, surface runoff and base flow in the basin show increases over the present as a result of future climate change. However, water resources in the basin will be less reliable in the future.
- This study used future climate series for one of the RCM, PRECIS for the impact analysis. Due to uncertainties in climate forecasting, the use of climate model ensembles and multiple scenarios will be useful for understanding the range of climate change impact that can be expected on the water resources in the Bhima river basin.
- The result of hydrological model calibration and validation indicated that the SWAT model simulates the stream flow appreciably well for the study area. The model performance criterion which is used to evaluate the model result, the coefficient of determination and the Nash-Sutcliffe simulation efficiency values obtained proved this fact.

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- Hydrological impact of future climate change scenarios indicated that there will be variation in mean annual water balance components from current to GHG scenarios shows that there has been increase in the annual precipitation. The increase in precipitation has been found more prominent for the period 2041-2070. For the period 2011-2040 there is slight decrease in surface runoff, where as for the period 2041-2070 surface runoff as well as annual water yield and actual evapotranspiration also likely to be increased. However, there is a decrease in soil moisture storage.
- This study used future climate series for one of the RCM, PRECIS for the impact analysis. Due to uncertainties in climate forecasting, the use of climate model ensembles and multiple scenarios will be useful for understanding the range of climate change impact that can be expected on the water resources in the Bhima river basin.

Thank you!