Climate Change and Its Impact on Water Resources of a River Basin

Prof. D. Nagesh Kumar

Department of Civil Engineering

Indian Institute of Science

Bangalore – 560012

URL: http://www.civil.iisc.ernet.in/~nagesh

Acknowledgement:

Drs A Anandhi , V V Srinivas &

Prof Ravi S Nanjundiah

Outline

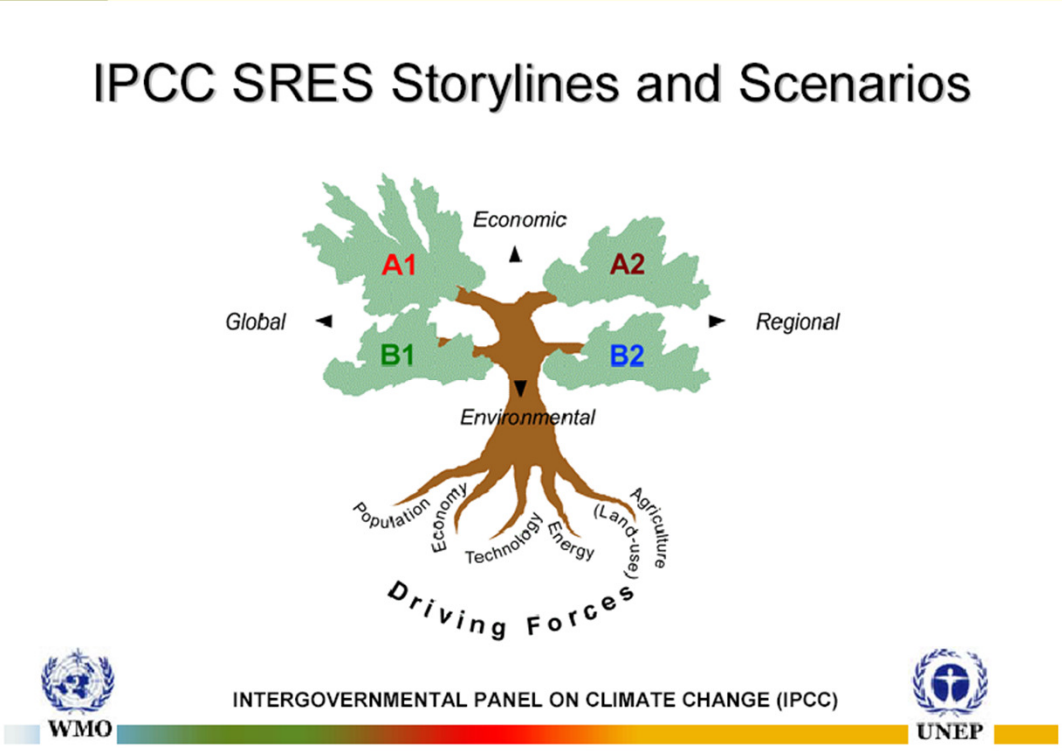
- **Introduction**
- **Climate Change**
  - IPCC Scenarios
  - Downscaling for Hydrologic Investigations
  - Downscaling of Hydro-meteorological Variables for a River Basin
- **Remote Sensing (RS), GIS & DEM for Hydrology**
  - RS for Land Use/ Land Cover
  - GIS for Watershed Delineation
  - DEM for Drainage Pattern Estimation using SRTM Data
- **Streamflow Projections using SWAT**
  - AV SWAT Model
  - Inputs for AV SWAT Model
  - Streamflow Projections
- **Conclusions**

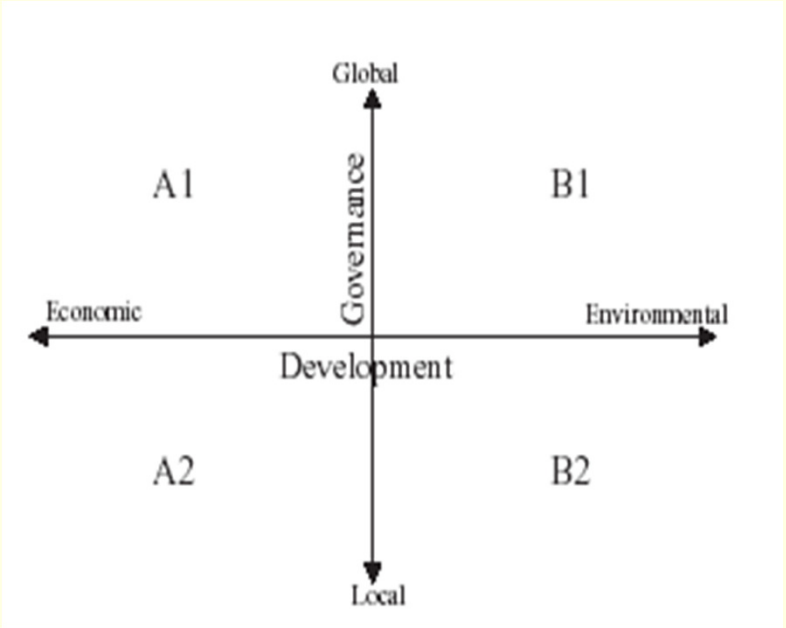
Climate Change Scenario

Climate Change scenario refers to a plausible future climate that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change and natural climate variability

IPCC - Intergovernmental Panel on Climate Change

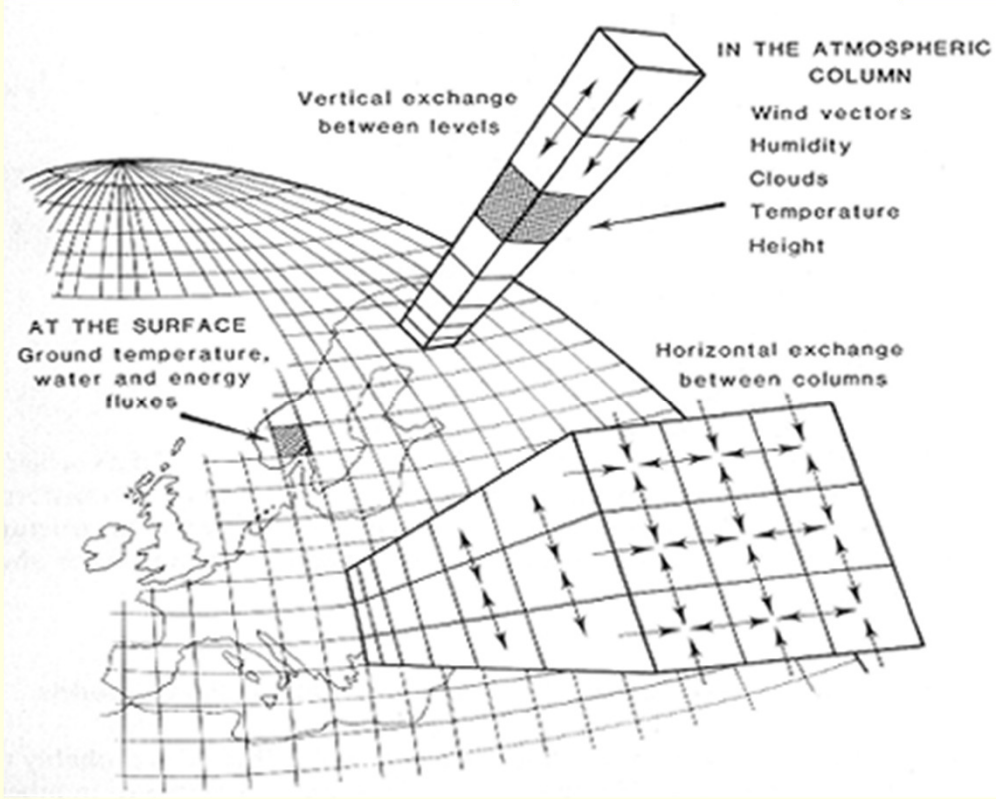
The 4 storylines describe the way world population, land use changes, new technologies, energy resources, economies and political structure may evolve over the next few decades.





Dynamics in GCM's

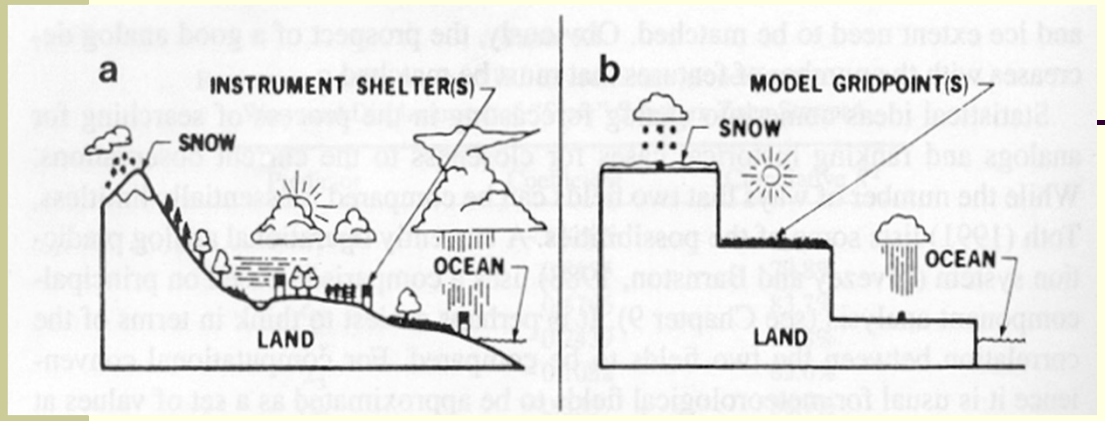
- Any GCM must be formulated with some fundamental considerations for
  - Conservation of momentum
  - Conservation of mass
  - Conservation of energy
  - Ideal gas law
- Computed either in rectangular grid space or in spectral space



Downscaling to River Basin Scale

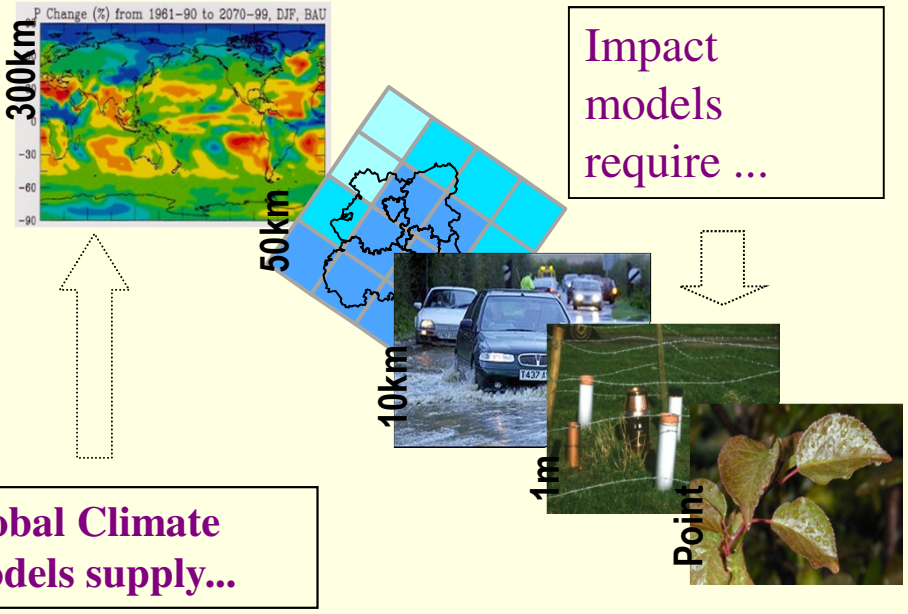
Schematic illustration of the

(a) real world **(b) world as represented by GCMs**



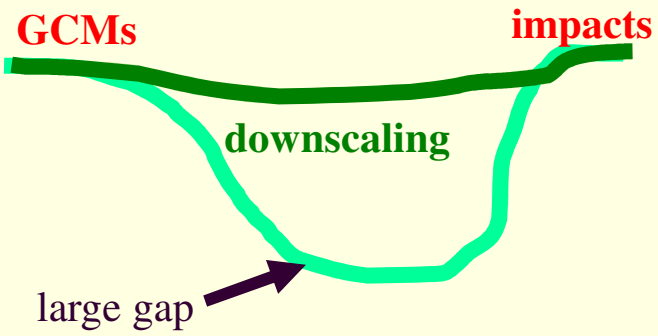
Courtesy: The Canadian Climate Impacts Scenarios (CCIS) Project

Small-scale affects (such as topography) important to local climate are poorly represented in GCM



Impact models require ...

Global Climate Models supply...



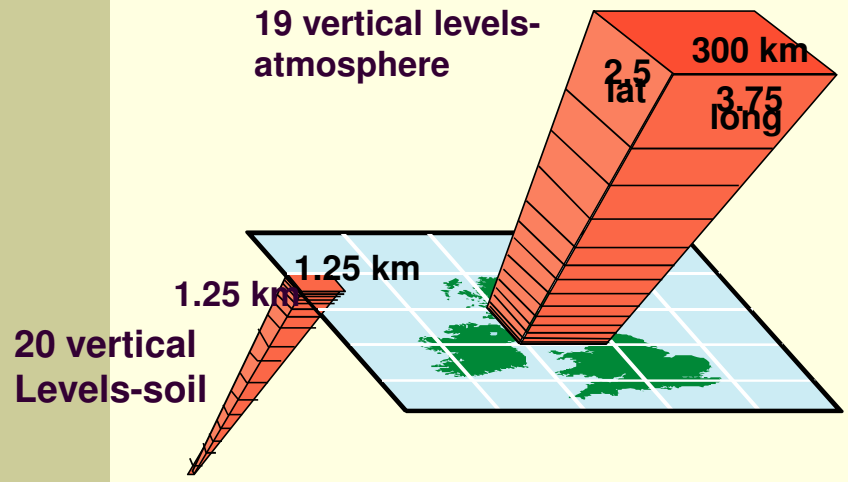
Courtesy: The Canadian Climate Impacts Scenarios (CCIS) Project

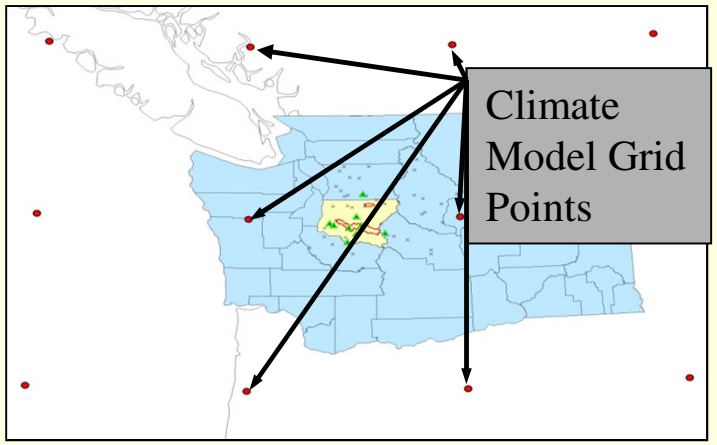
Downscaling Methods

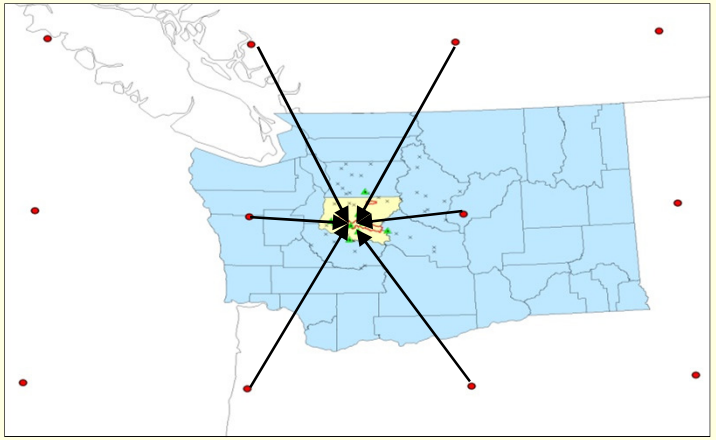
R = F(L)

- **Dynamical Downscaling**
  - F is modeled dynamically (through RCM)
- **Statistical Downscaling**
  - F is modeled empirically from observational (or modeled) data

R = F(L)







two way nesting

RCM and GCM run simultaneously

Feedback from RCM to GCM

one way nesting

Driving RCM with GCM

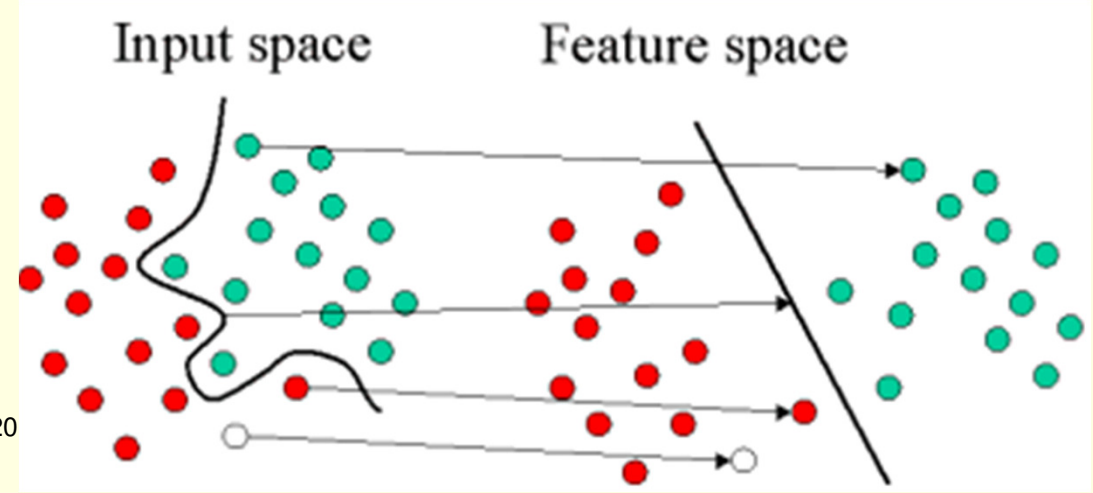
No feedback from RCM to GCM

GCM

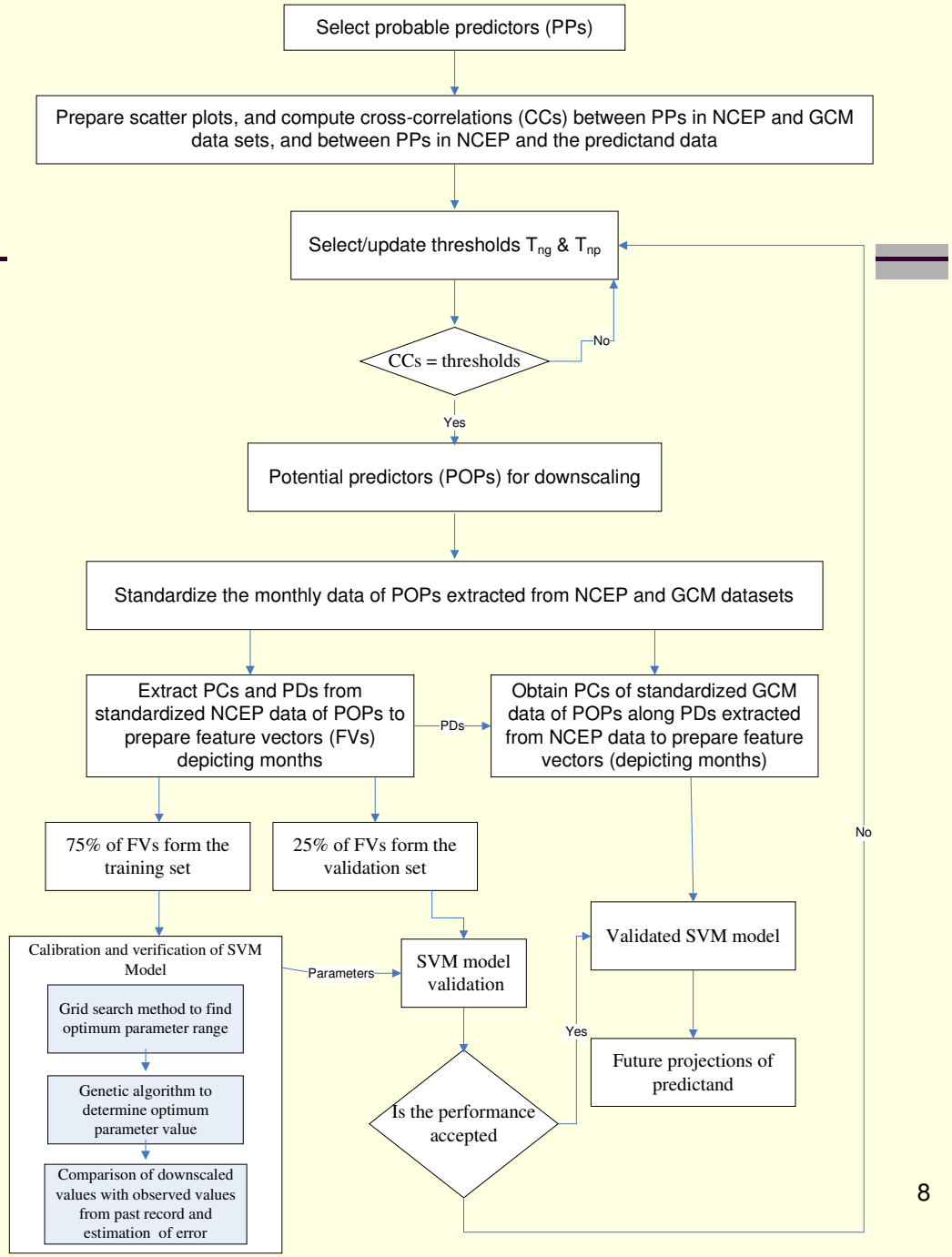
RCM

Support Vector Machine

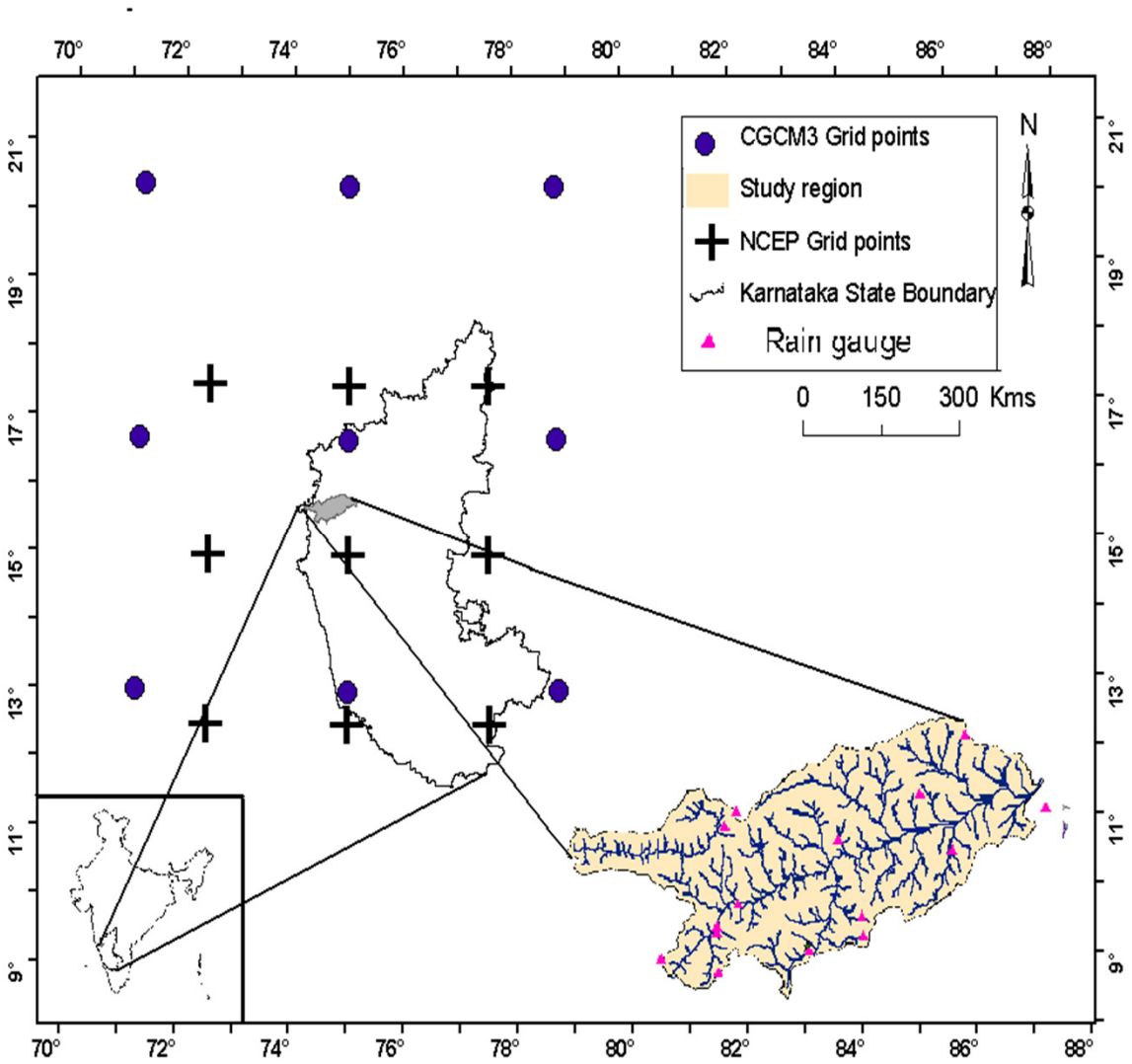
- The SVM uses kernel functions to transform the data to a higher, possibly infinite, dimensional space.
- A linear solution, in the higher dimensional feature space, corresponds to a non-linear solution in the original lower dimensional input space.
- The mapped objects are linearly separable
- An optimal line is constructed rather than a complex curve to separate objects



Methodology for Downscaling using SVM



Malaprabha Basin



Map showing NCEP & GCM grid points and rain gauge locations in Malaprabha reservoir catchment

- Part of Krishna Basin in Karnataka
- The climate of the study region is dry, except in monsoon months
- Avg. annual rainfall:1051mm
- Catchment Area:2564 sq km

- GCM output is downscaled using Support Vector Machine (SVM)
- Six Cardinal variables are downscaled
  - Precipitation
  - Maximum Temperature
  - Minimum Temperature
  - Wind Speed
  - Relative Humidity
  - Solar Radiation

Predictors for downscaling different hydrometeorological variables

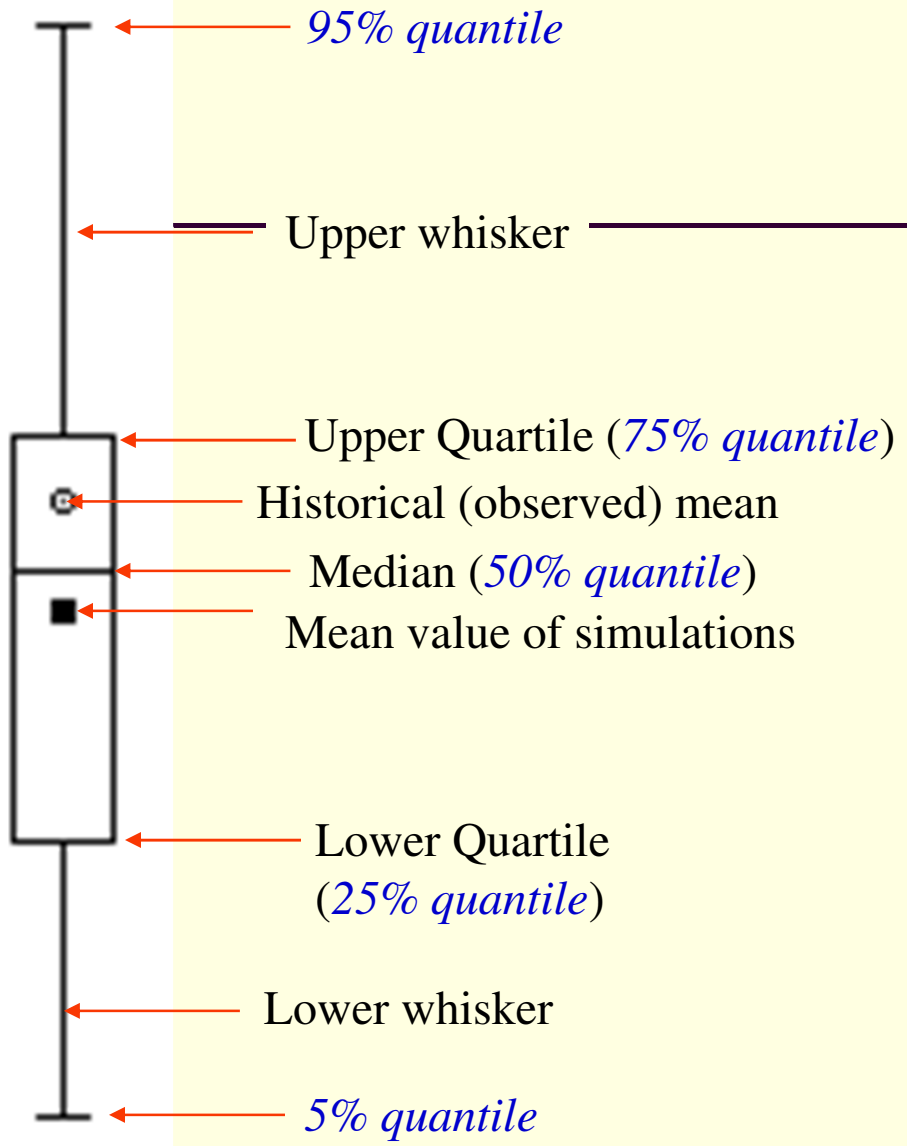
Sl. No.	Predictors (Spatial resolution of 2.5° X 2.5° ≈ 75,000 km^2)	Predictand (river basin scale ≈ 2500 km^2)
1	Temperature at 925mb, 700mb, 500mb, 200mb (Ta 925, Ta 700, Ta 500, Ta 200), geo-potential height at 925mb, 500mb, 200mb (Zg 925, Zg 500, Zg 200), specific humidity at 925mb, 850mb (Hus 925, Hus 850), zonal (Ua) and meridional wind velocities (Va) at 925mb, 200mb (Ua 925, Va 925, Ua 200, Va 200), precipitable water (prw) and surface pressure (ps).	Precipitation
2	Group A – Ta 925, Ua 925, Va 925 Group B – latent heat, sensible heat, shortwave radiation and longwave radiation fluxes Group C – comprises of all predictors in Groups A and B	Max. & Min. Temperature

Predictors for downscaling different hydrometeorological variables – contd..

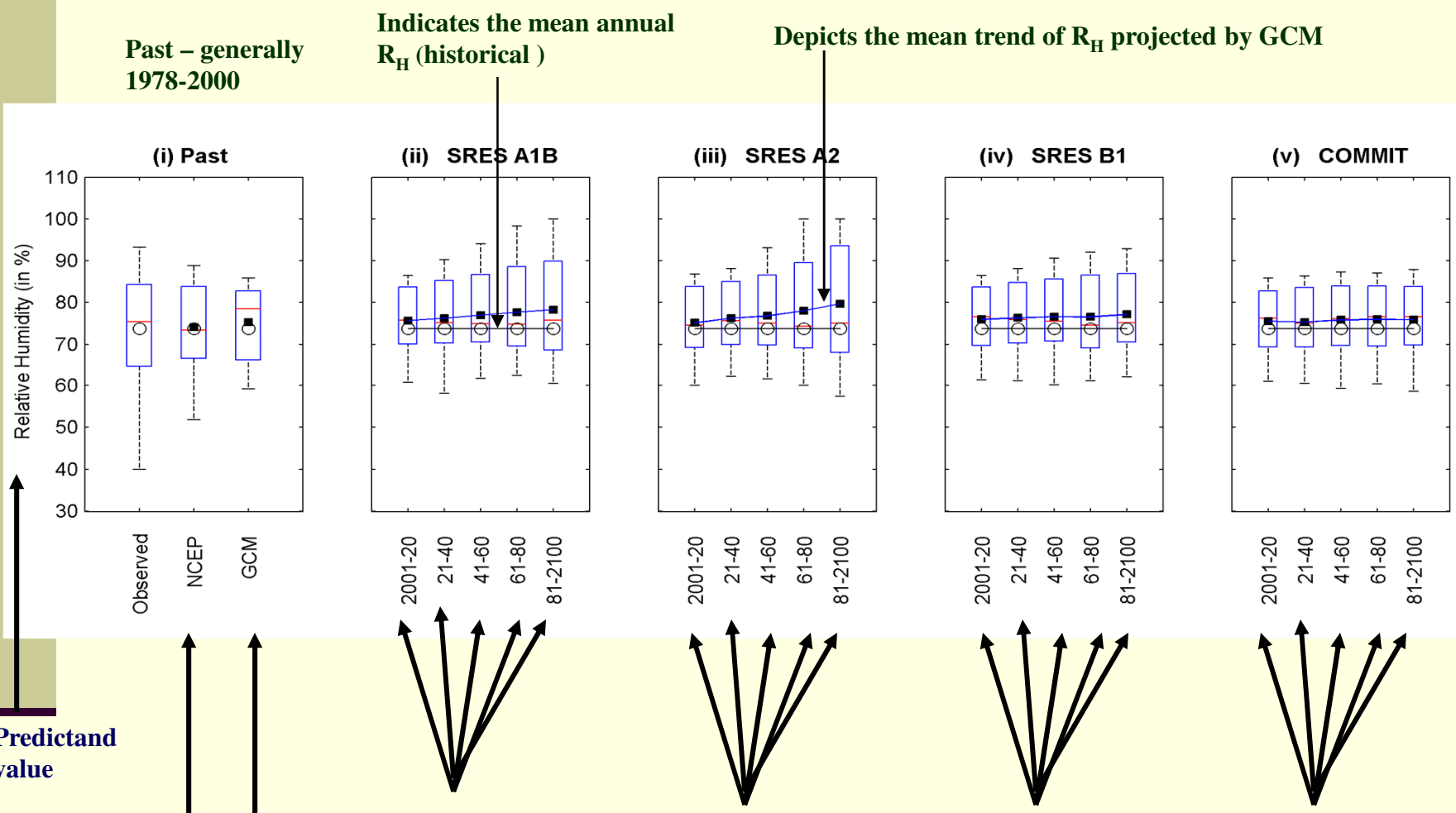
Sl. No.	Predictors (Spatial resolution of 2.5° X 2.5°)	Predictand (river basin scale)
3	Ua 925, Va 925	Wind speed
4	Ta 925, Hus 925, Ta sur, and LH	Relative humidity
5	Precipitable water	Cloud cover
6	Group A – 15 predictors, same as predictors selected for precipitation *Group B –precipitation, max. & min. temperature, wind speed, relative humidity, cloud cover	Streamflow

*** at river basin scale**

BOX PLOT

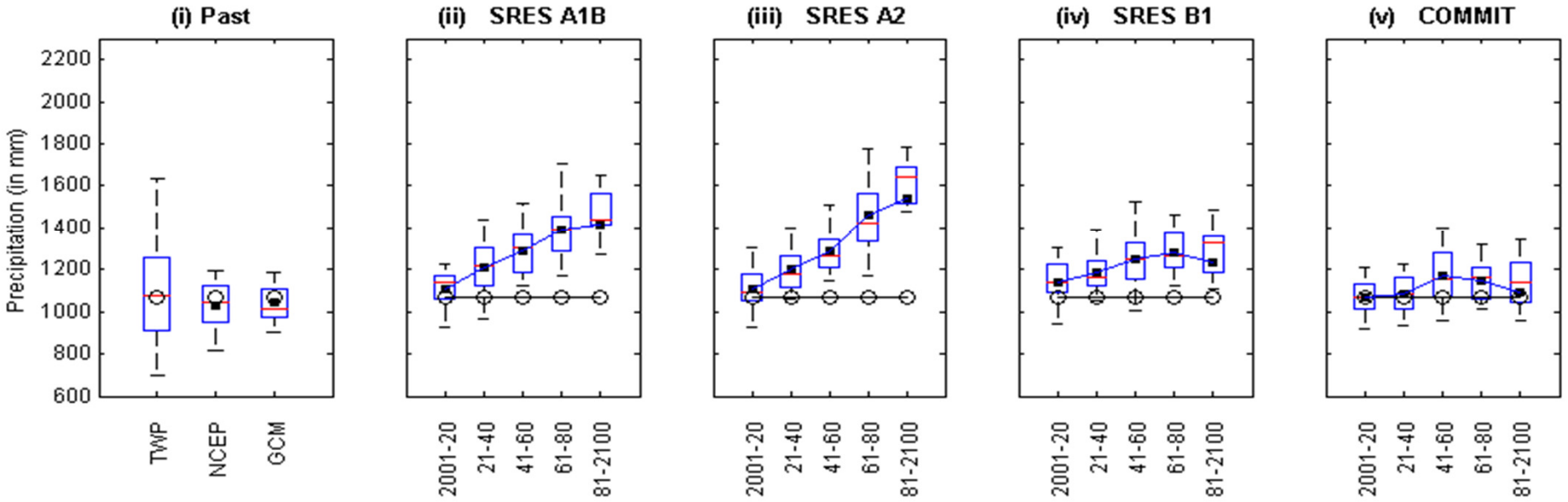

95% quantile
Upper whisker
Upper Quartile (75% quantile)
Historical (observed) mean
Median (50% quantile)
Mean value of simulations
Lower Quartile
(25% quantile)
Lower whisker
5% quantile

Downscaling RH* from CGCM3 for different Scenarios



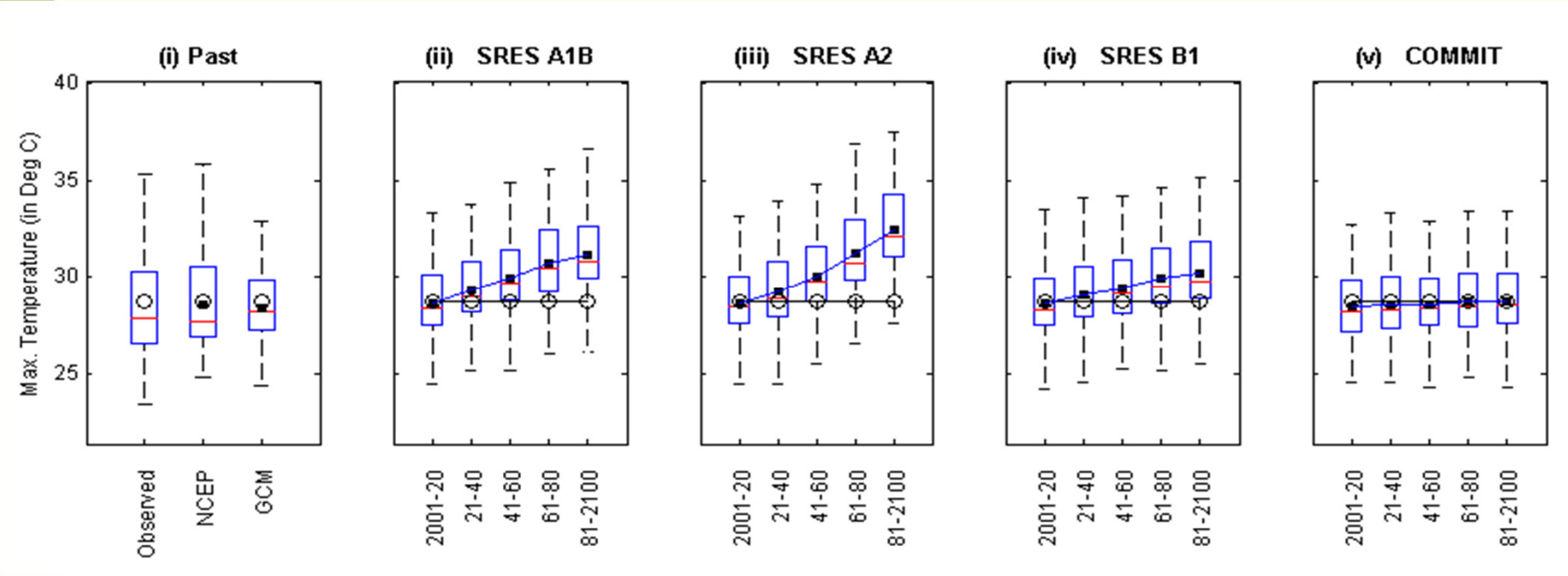
* Theoretical and Applied Climatology, Springer, 2012

Downscaled Rainfall from CGCM3 for different Scenarios*



* International Journal of Climatology, Royal Meteorological Society (RMetS), UK, 2008

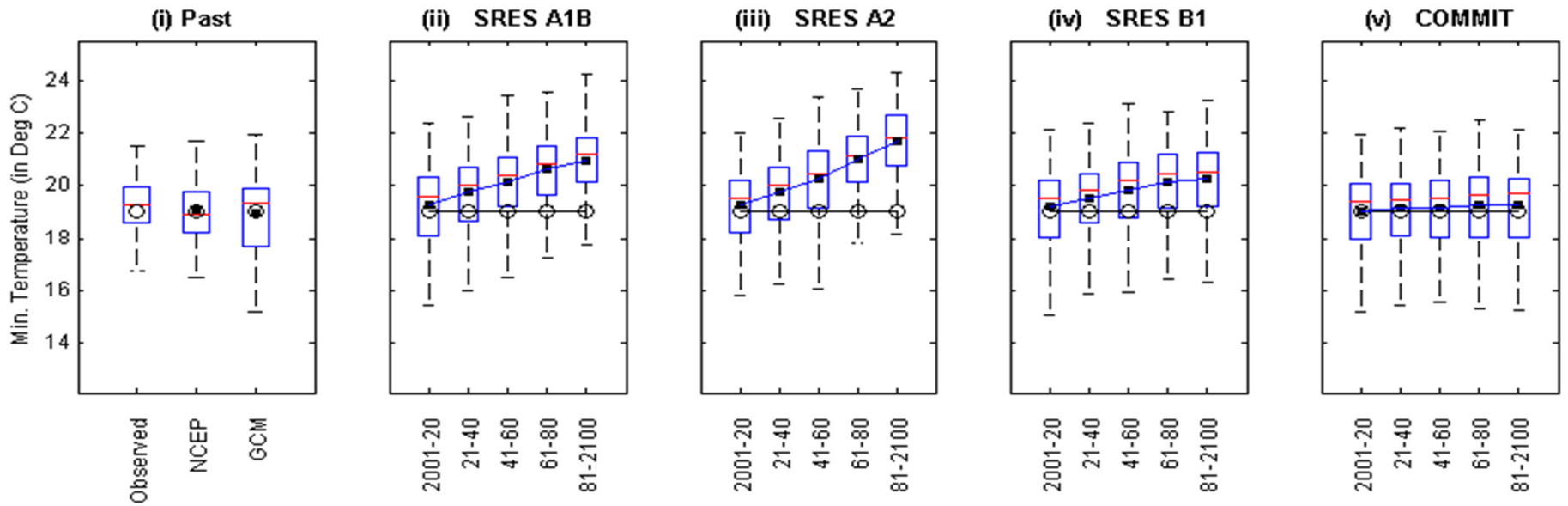
Downscaled Maximum Temperature*



- Results show that T_{max} is projected to increase in future for A1B, A2, and B1 scenarios.
- Projected increase in T_{max} is high for A2 scenario, whereas it is least for B1 scenario. This is because among the scenarios considered, the scenario A2 has the highest concentration of carbon dioxide (CO_2) equal to 850 ppm, while the same for A1B, B2 and COMMIT scenarios are 720 ppm, 550 ppm and ≈370 ppm respectively.

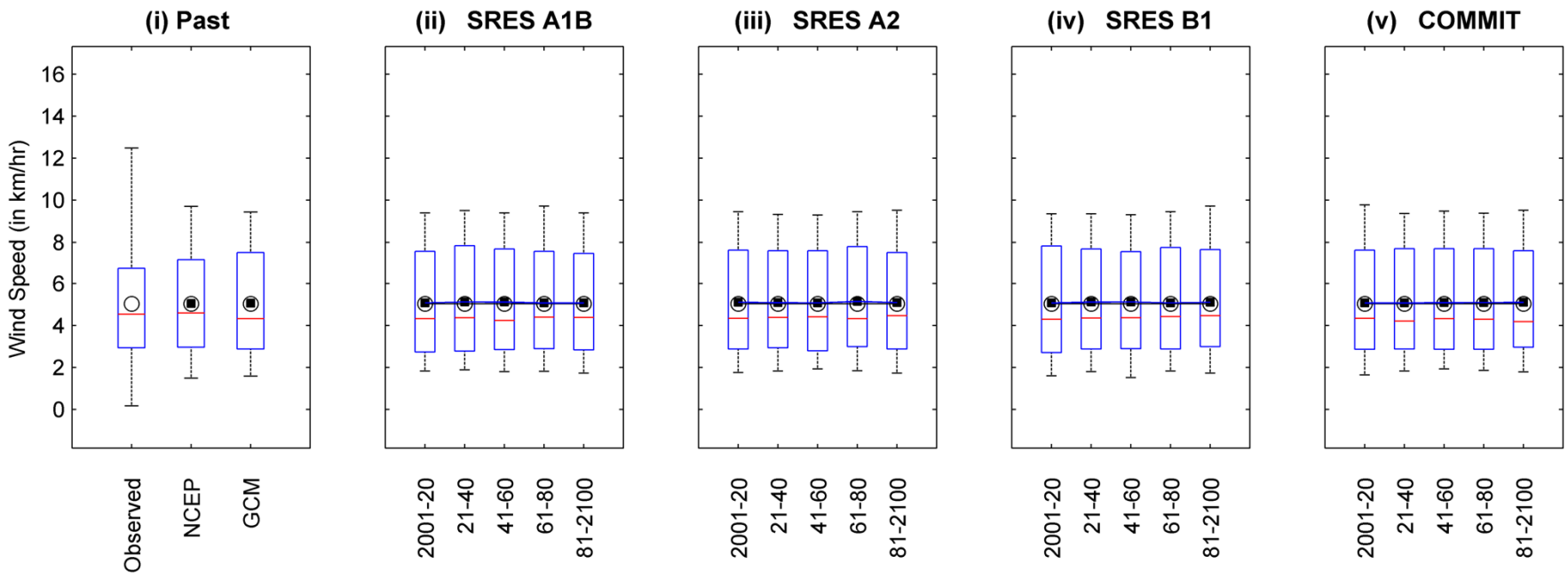
* International Journal of Climatology, Royal Meteorological Society (RMetS), UK, 2009

Downscaled Minimum Temperature*

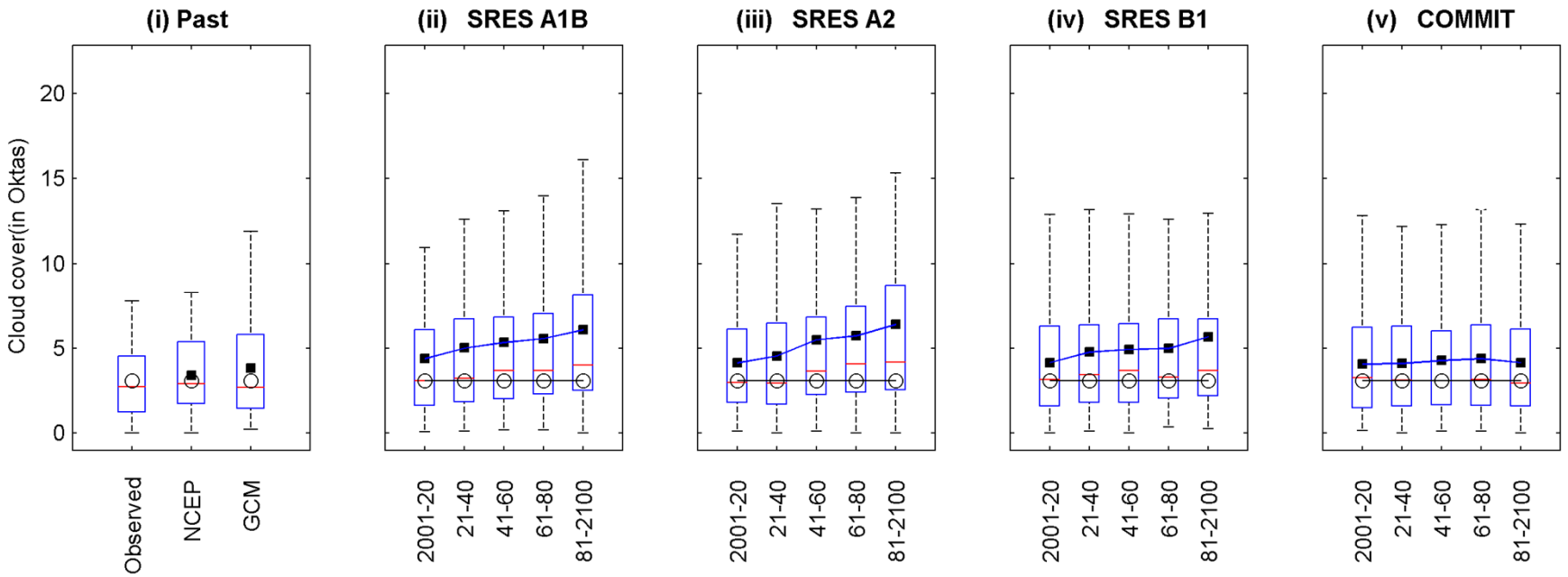


* International Journal of Climatology, Royal Meteorological Society (RMetS), UK, 2009

Downscaled Wind Speed

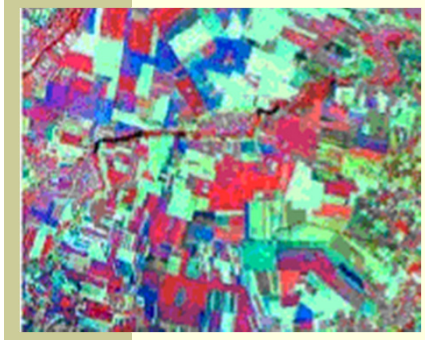


Downscaled Cloud Cover

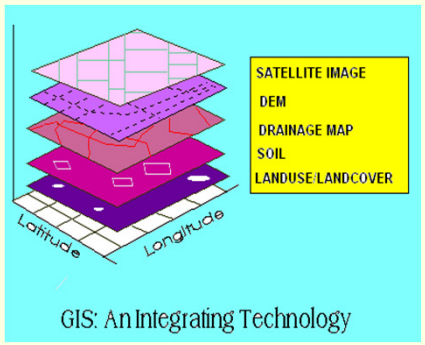


Solar radiation is obtained from downscaled cloud cover and temperature data

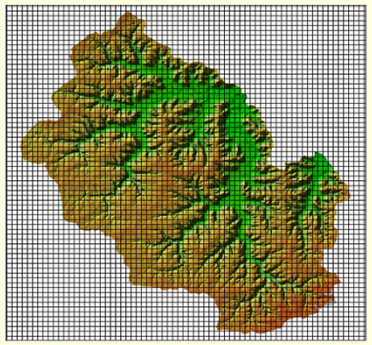
Integration of RS, GIS, DEM and Hydrological Models



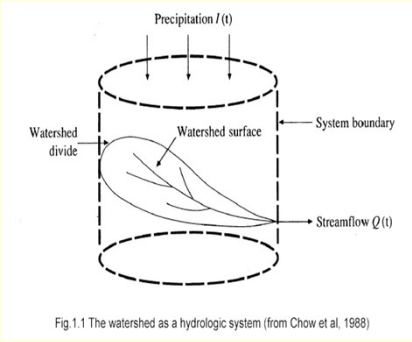
RS



GIS



DEM



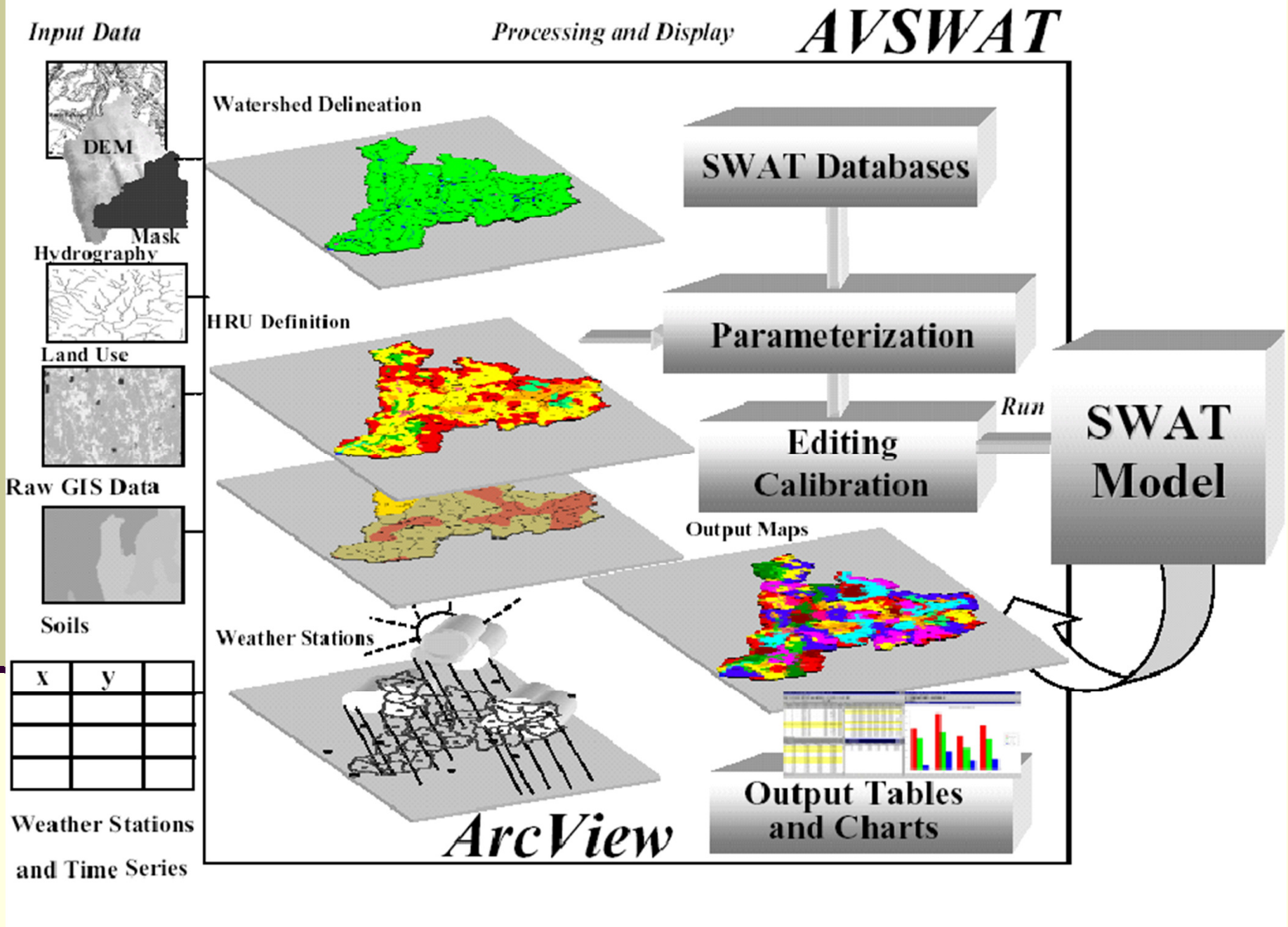
Hydrological Model

Integration of RS, GIS, DEM and Hydrological Models

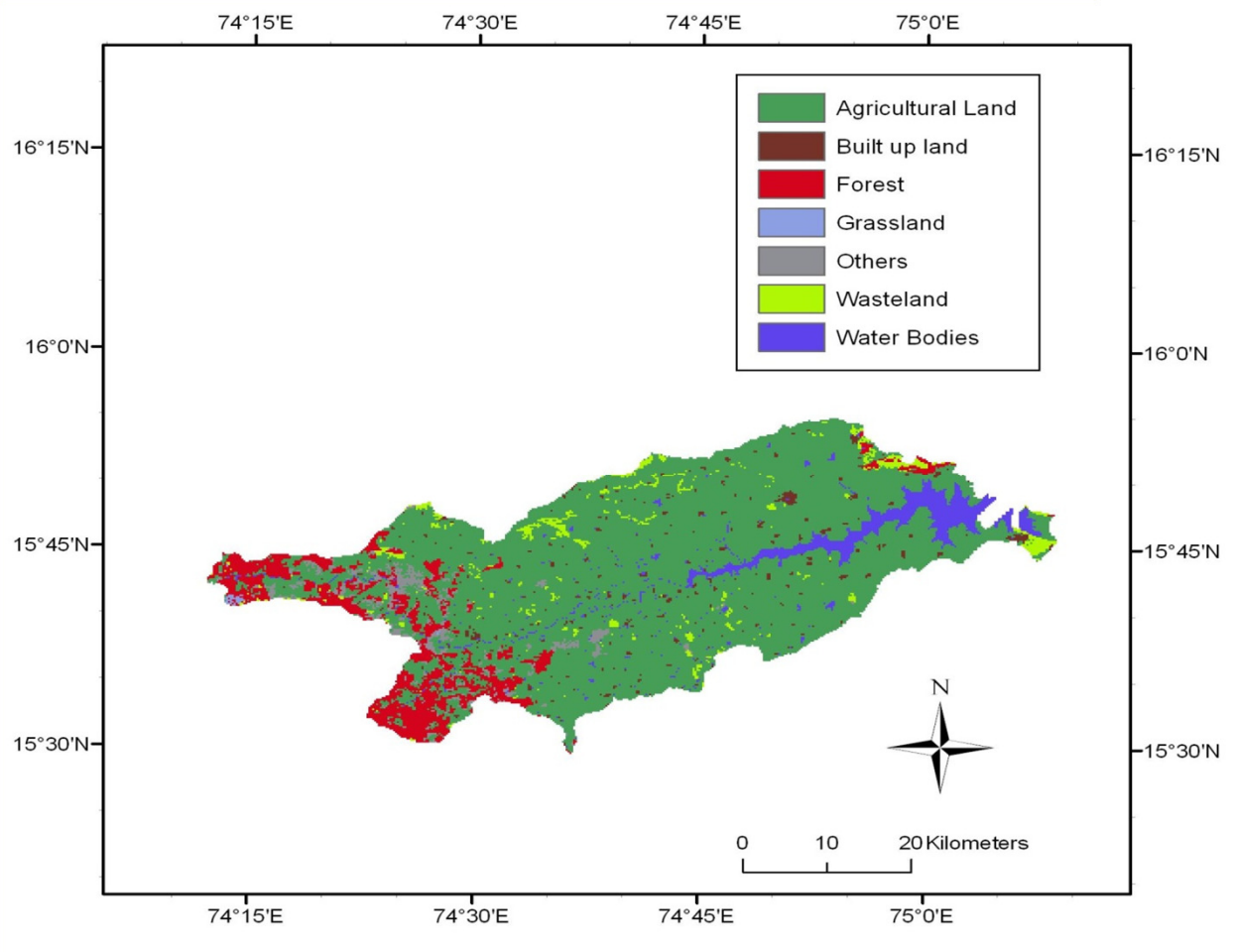
- Hydrological model is a good tool for understanding and managing phenomena related to hydrological processes
- RS provides essential inputs for hydrologic models
- GIS provides a platform for simulation of hydrological model
- DEM provides inputs essential for topography
- RS, GIS & DEM combined with mathematical models provide a convenient platform for handling, compiling and presenting large amounts of spatial data essential to river basin management

Soil and Water Assessment Tool (SWAT)

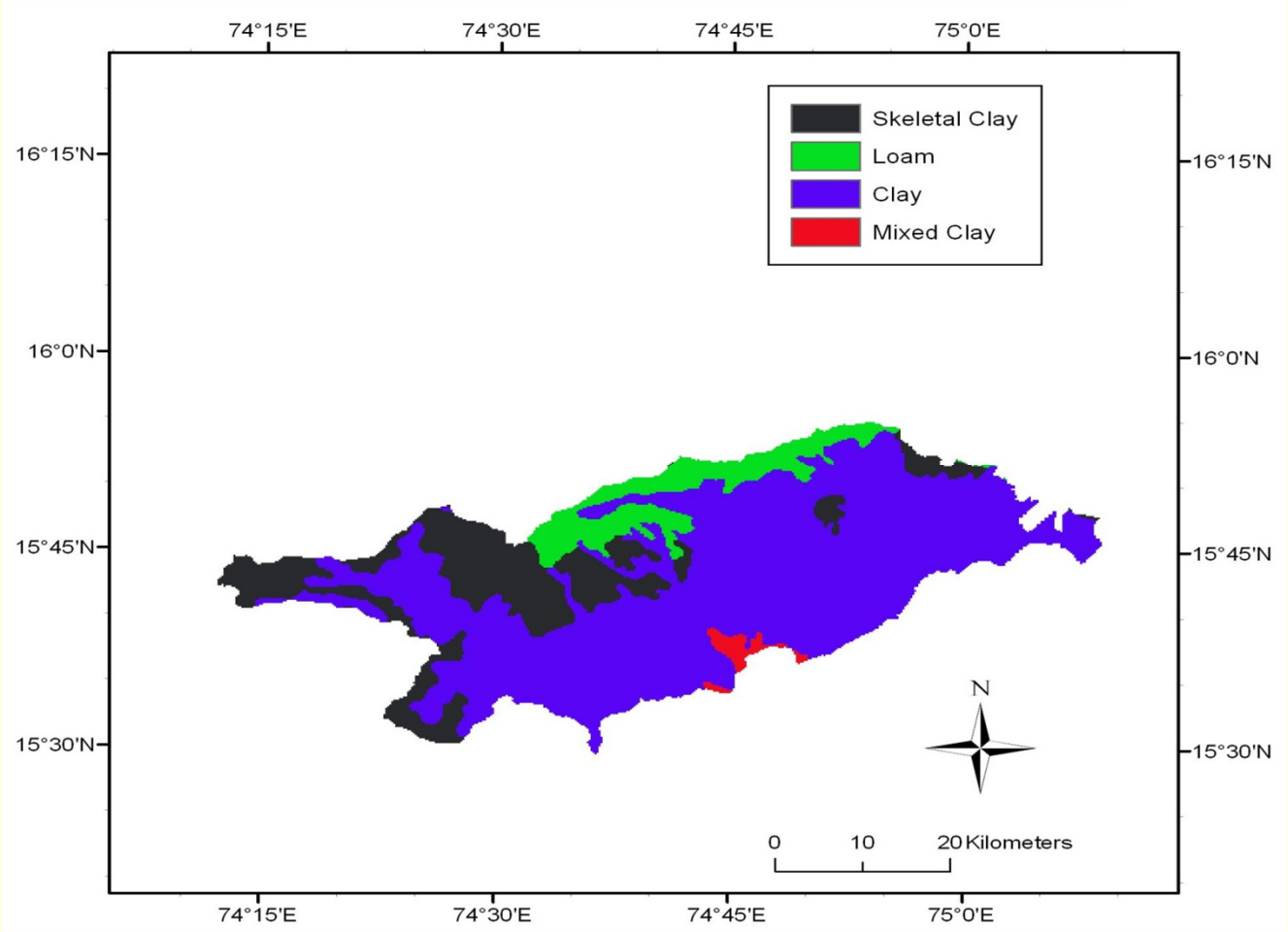
- SWAT is a river basin, or watershed scale model (Neitsch et al., 2002)
- Physically based & Continuous time model
- To predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time.
- Due to its easy adaptability to situations with limited data availability, it has become very popular even to study the climate change impact on a river basin scale


Input Data
Processing and Display
AVSWAT
DEM
Mask
Hydrography
Land Use
Raw GIS Data
Soils
x
y
Weather Stations
and Time Series
Watershed Delineation
HRU Definition
Weather Stations
ArcView
SWAT Databases
Parameterization
Editing
Calibration
Run
SWAT
Model
Output Maps
Output Tables
and Charts

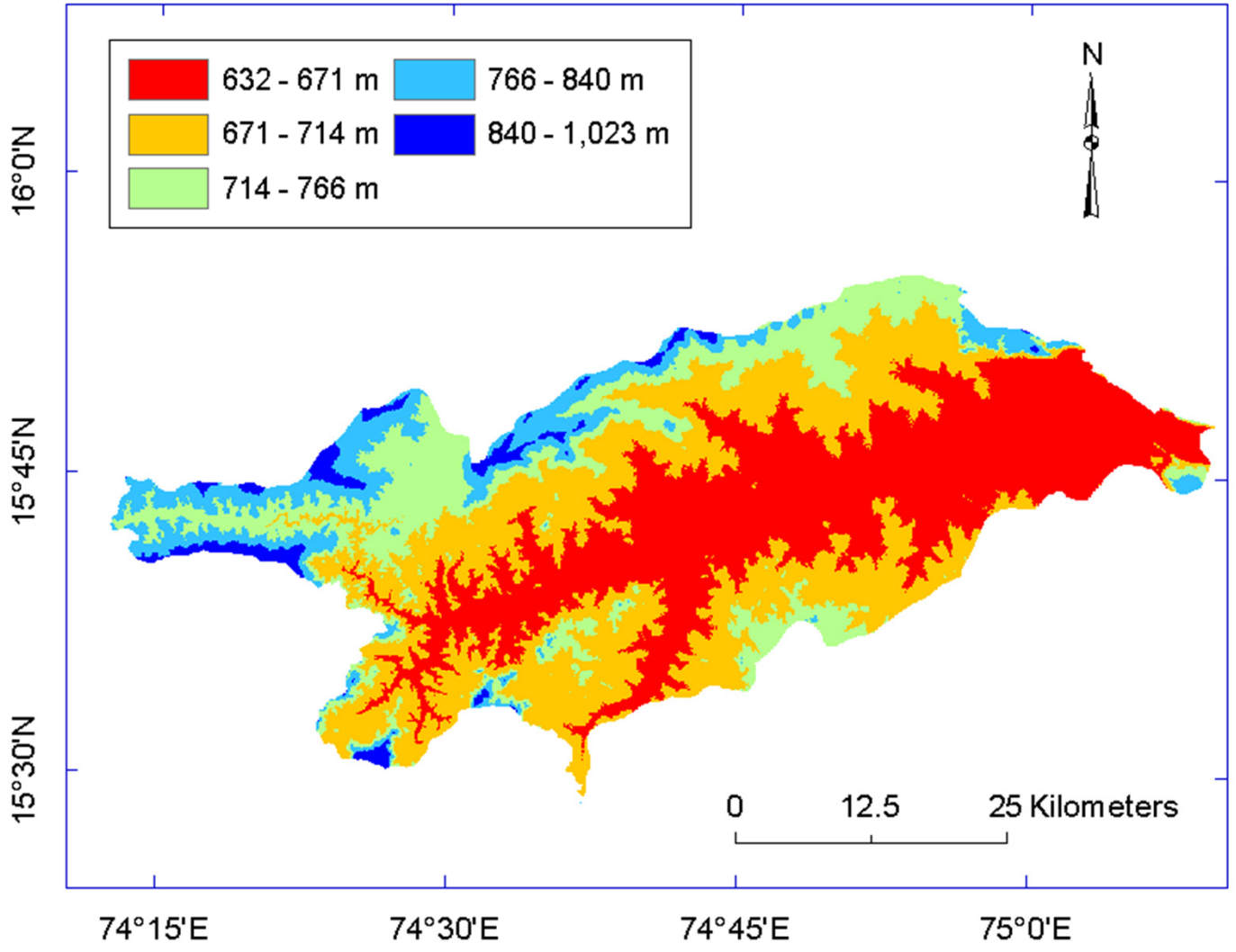
Land use/ land cover theme of the Malaprabha reservoir catchment derived from IRS data



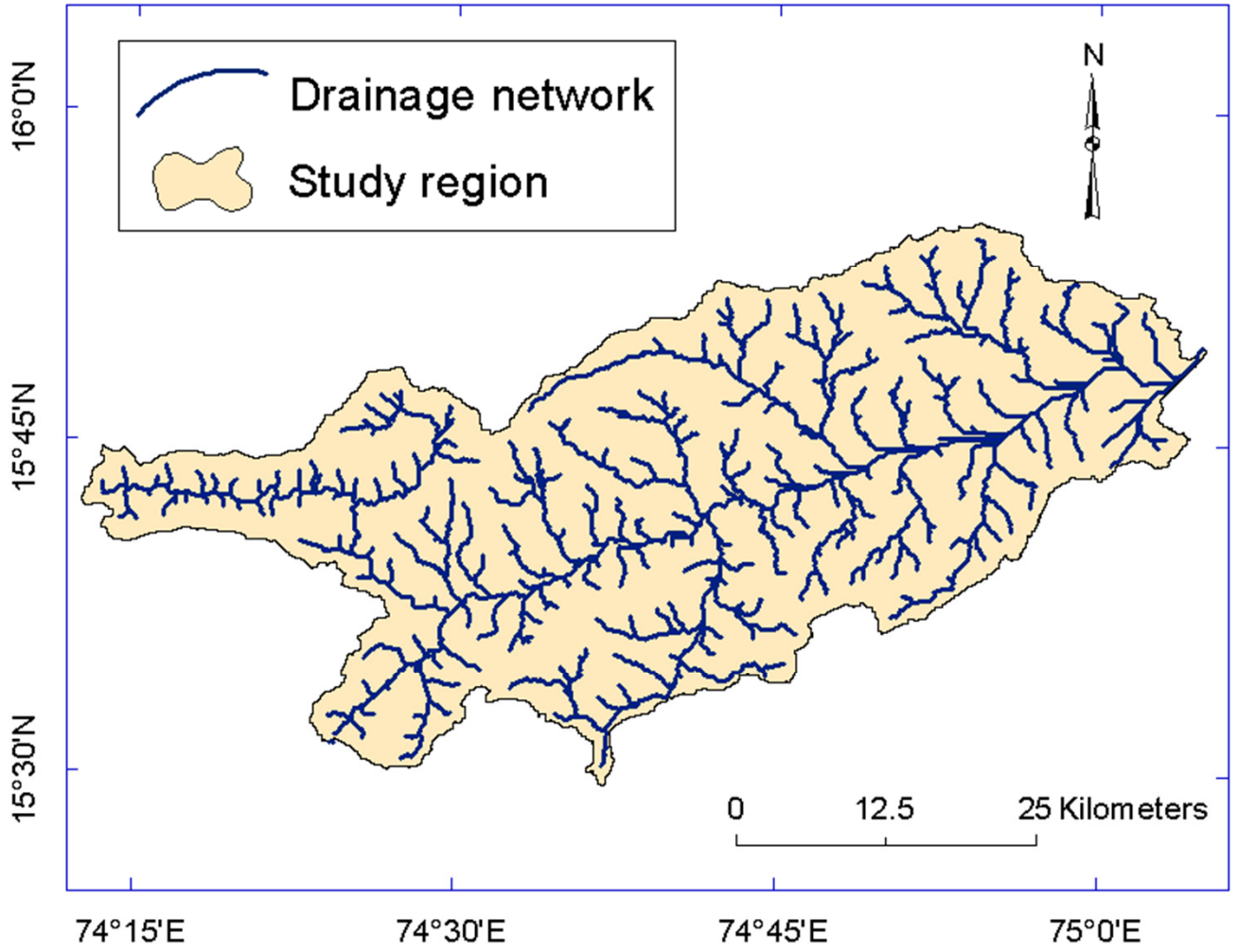
Major soil groups in the Malaprabha reservoir catchment derived from RS and NBSS & LUP, Nagpur



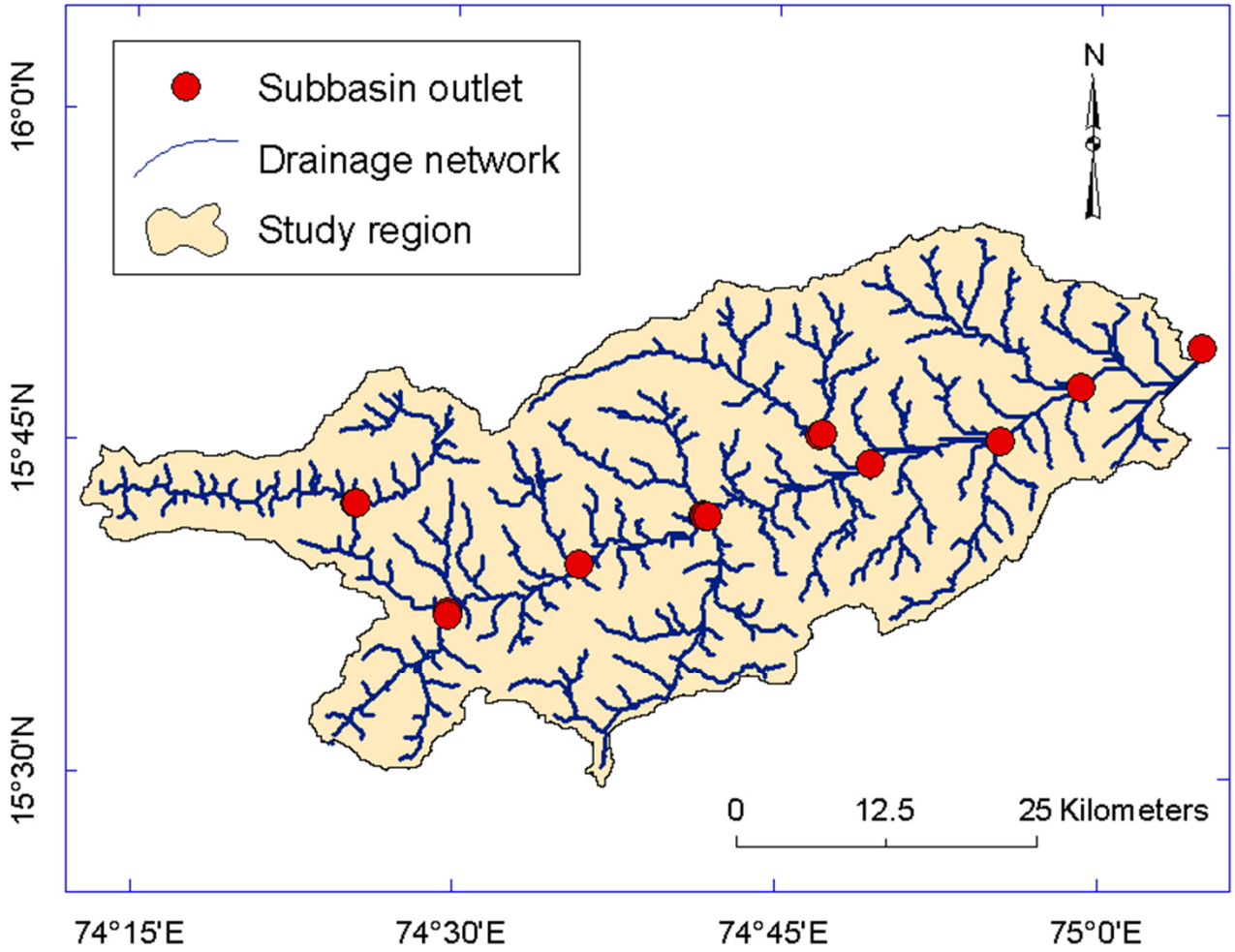
DEM of the catchment of Malaprabha reservoir



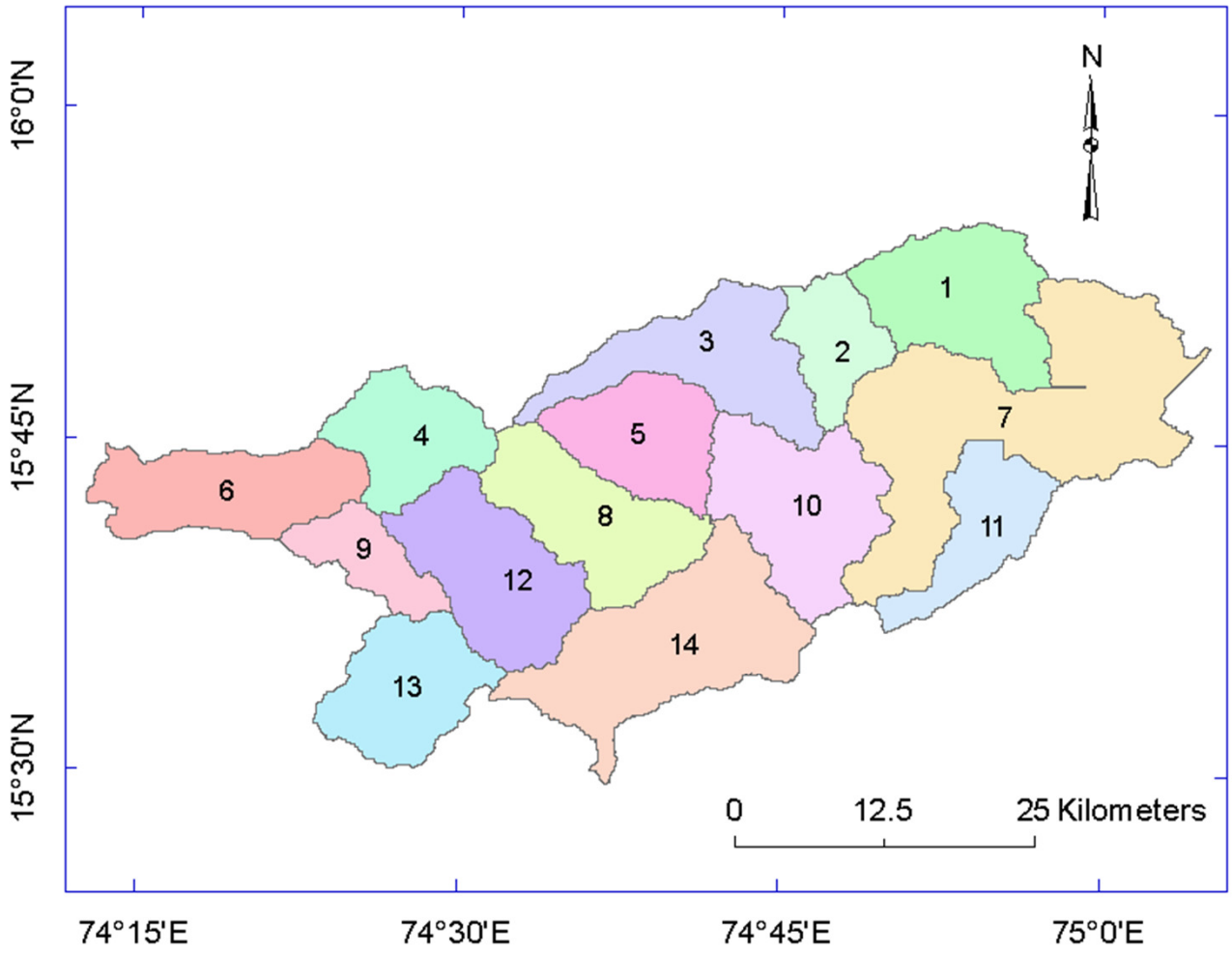
Stream network in the catchment of Malaprabha reservoir obtained from AVSWAT model using DEM



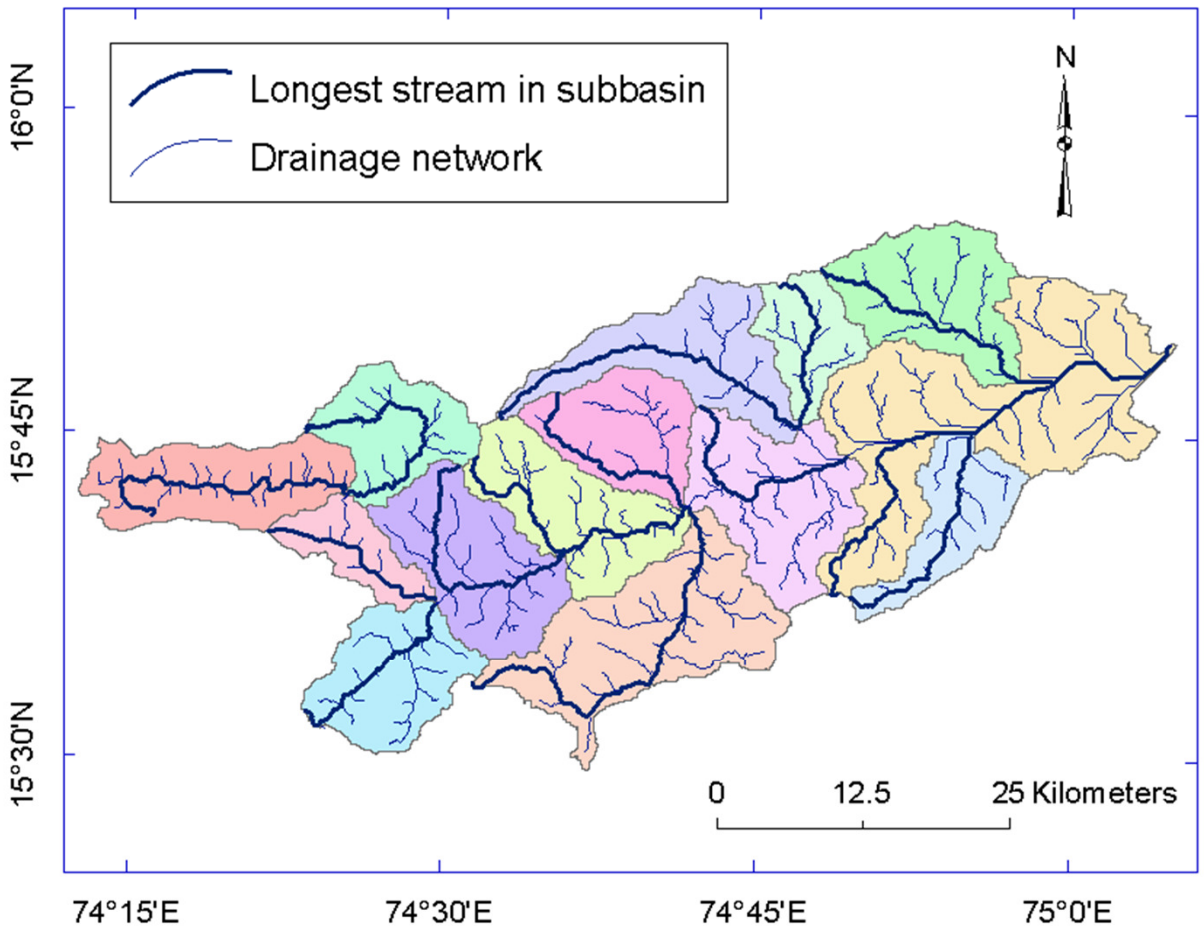
Drainage sub-basin outlets that are fixed in the catchment of Malaprabha



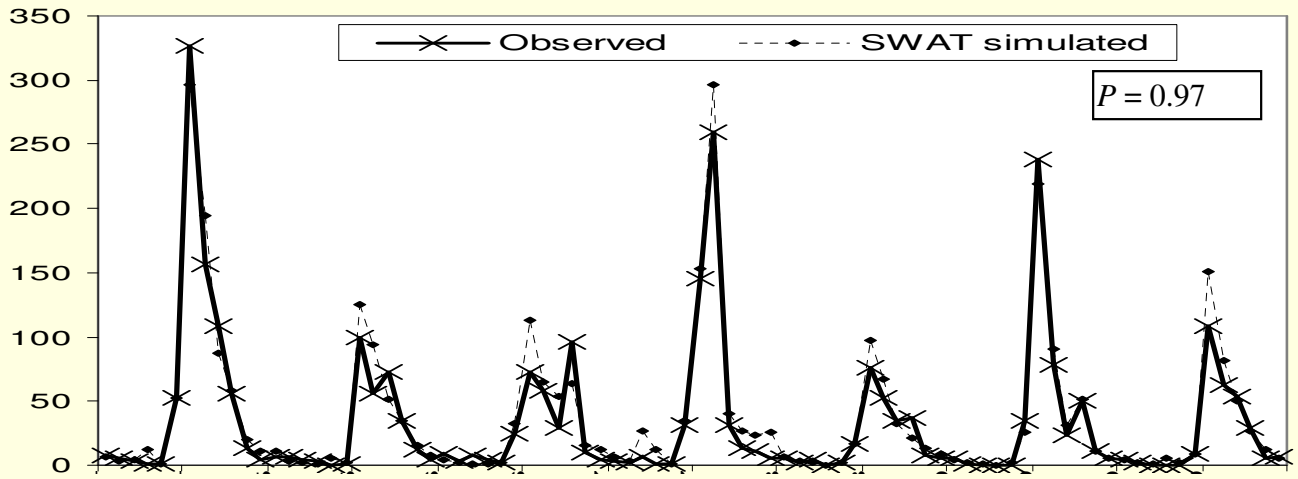
Sub-basins formed by AVSWAT for the outlets fixed in the catchment of Malaprabha reservoir



Longest stream in each sub-basin obtained from AVSWAT model

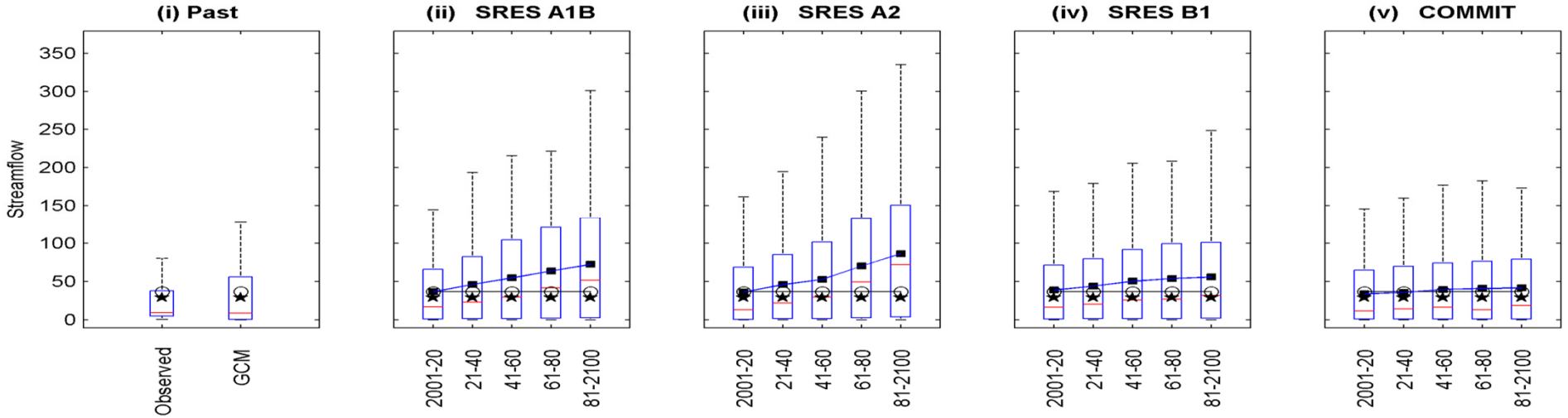


Model performance during the validation period (1994 –2000)



Observed and simulated monthly streamflows (in mm)

Streamflow projections made for various IPCC scenarios for Malaprabha Basin obtained from AV-SWAT model



Streamflow in mm

Conclusions

- Climate change and its variability will have significant impact on Hydrology of river basin
- It is important to understand and quantify these impacts
- Remote Sensing, GIS and DEM are very useful tools to assess water resources of a river basin
- Impact of climate change on hydrology and water resources should be investigated for effective planning and management of water resources

Thank you