SWAT Application for Snow Bound Karkheh River Basin of Iran

Hamid R. Solaymani

PhD Scholar, Department of civil Engineering - IIT Delhi -New Delhi - 110016 - India

E-mail: h.solaymani@civil.iitd.ac.in or hrsolaymani@yahoo.com

A.K.Gosain

Professor and Head of Department of civil Engineering - IIT Delhi - New Delhi -110016 - India

(http://www.iitd.ac.in)

E-mail: gosain@civil.iitd.ac.in

Soil & Water Assessment Tool SWAT

भारतीय प्रौद्योगिकी संस्थान दिल्ली
Indian Institute of Technology Delhi

Motivation

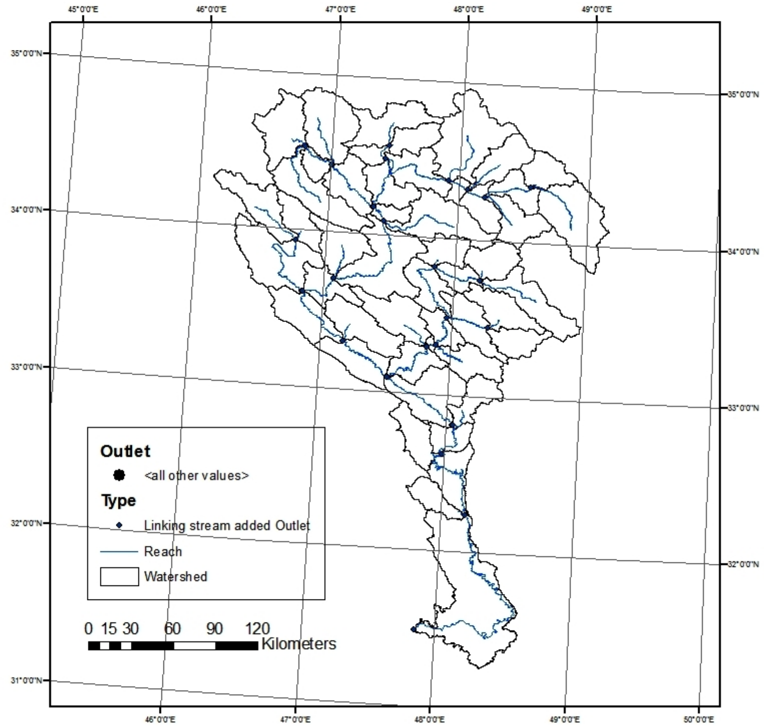
- In order to evaluate the general performances of different calibration methods, SWAT was applied to KARKHEH river basin (KRB)
- KRB is the heterogeneous basin in case of:
  - Precipitation
    - Snow bound
    - Rainfall pattern
  - Topographic condition
    - Plain area
    - Mountain area
  - Geologic formation
    - Include various formations which could be various effect on rainfall- runoff process
  - Area

Study Area

- The KRB is located in the western part of Iran. The drainage area of the basin is about 50,764 km^2, out of which 80% falls in the Zagros mountain ranges

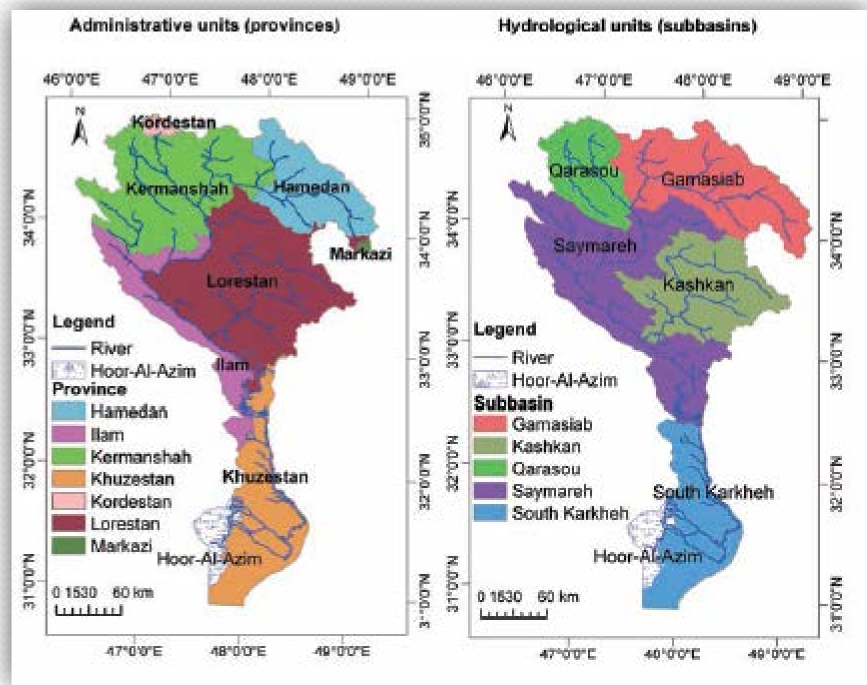
- The topography depicts large spatial variation with elevations ranging from 3 to more than 3,500 masl. The elevation of about 60% of the basin area is 1,000-2,000 masl and about 20% is below 1,000 masl

- The precipitation (P) pattern depicts large spatial and intra-and inter-annual variability across the basin. The mean annual precipitation ranges from 150 mm/yr. in the lower arid plains to 750 mm/yr. in the mountainous parts

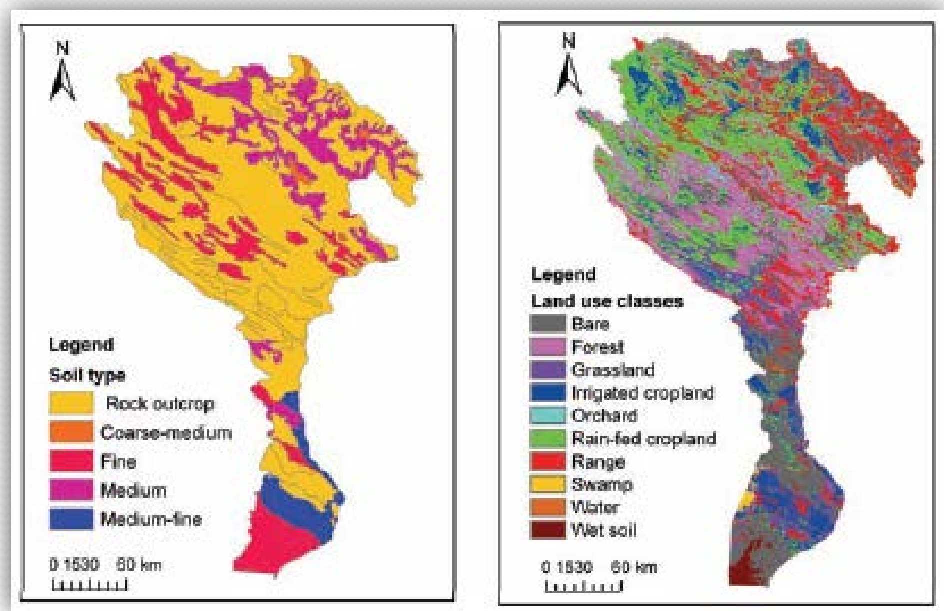


Study Area

Administrative & Hydrological units



Soil & Land-use



Snow Role

Most of precipitation in this region occurs in the cold season and a good portion is in the form of snow, the snow water equivalent (SWE) for the mountainous parts of the KRB is about 75 mm/yr. The amount and distribution of snow are strongly influenced by elevation, varying from 44 mm/yr. for elevations less than 1,500 masl to 245 mm/yr. with elevation more than 3,500 masl

Model Setup

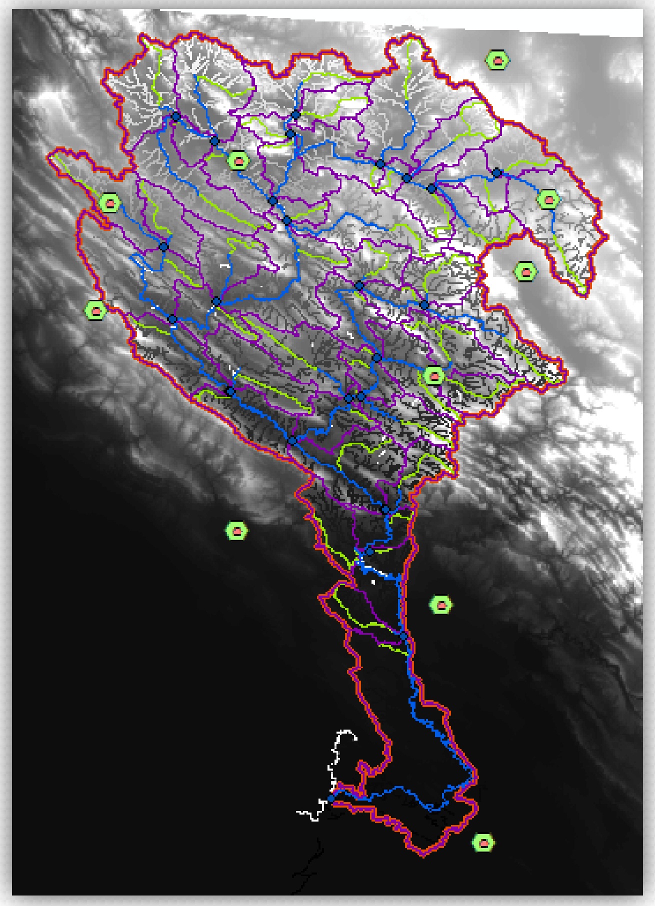
• The Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) of 90 m resolution was used for sub-basin definition (49 sub-basin)

• The land use/land cover map was prepared using fine resolution Landsat ETM+(2002)

• The soil map was obtained from the global soil map of the FAO (1995)

• Daily climatic data for the period from January 1982 to December 2005 were used for the model simulations (Precipitation and temperature data from 13 synoptic stations)

• Daily discharge data for 24 stages (1982 to 2005); gives us the possibility for each sub-basin



Sensitivity Analysis

- It is the prior step to model calibration to demonstrates the impact that change to an individual input parameter has on the model response and can be performed using a number of different methods
- The method in the Arc-SWAT Interface combines the Latin Hypercube (LH) and One-factor-At-a-Time (OAT) sampling and the sensitivity analysis tool has the capability of performing two types of analyses:
  - The first type of analysis uses only modelled data to identify the impact of adjusting a parameter value on some measure of simulated output, such as average stream-flow
  - The second type of analysis uses measured data to provide overall "goodness of fit" estimation between the modelled and the measured time series
- The first analysis may help to identify parameters that improve a particular process or characteristic of the model, while the second analysis identifies the parameters that are affected by the characteristics of the study watershed and those to which the given project is most sensitive (Veith and Ghebremichael, 2009)

Sensitivity Analysis

No	Parameter	Description	Initial value	Rank No. *	Rank No. **
1	ALPHA_BF	Baseflow alpha factor (Days)	0-50	2	4
2	CANMX	Maximum canopy storage (mmH_2O)	0-10	10	16
3	CH_K2	Channel Effective Hydraulic Conductivity	0-150	4	15
4	CH_N2	Manning Coefficient for Channel	0.01-0.3	6	5
5	CN2	Initial SCS Runoff Curve number for Wetting Condition-2	±20%	1	1
6	EPCO	Plant uptake compensation factor	0-1	14	20
7	ESCO	Soil Evaporation Compensation Factor	0-1	3	3
8	GW_DELAY	Ground Water Delay Time	0-50	11	10
9	GW_REVAP	Ground Water "REVAP" Coefficient	0.02-0.2	15	19
10	GWQMN	Threshold Depth for shallow aquifer for flow	0-5000	13	2
11	RCHRG_DP	Deep Aquifer Percolation Factor	0-1	7	12
12	REVAPMN	Threshold Depth of water in shallow aquifer for "REVAP"	0-500	16	18
13	SFTMP	Snowfall temperature (°C)	-5-5	20	6
14	SLOPE	Slope steepness (m/m)	0-0.6	9	13
15	SMFMN	Melt factor for snow December 21 (MM H_2O/°C-day)	0-10	20	8
16	SMFMX	Melt factor for snow June 21 (mm H_2O/°C-day)	0-10	20	11
17	SMTMP	Snow melt base (°C)	-5-5	8	7
18	SOL _AWC	Soil Available Water Capacity	0.01-0.5	20	14
19	SURLAG	Surface Runoff Lag Time	0-10	5	5
20	TIMP	Snow pack lag temperature lag factor	0-1	12	9

*without observed data - **with observed data

Calibration and Validation

- For this study, two approaches have been used for calibration (Based on daily time steps data):
  - The manual and (One–factor-At–a-Time (OAT) sampling has been used)
  - The auto-calibration (The Sequential Uncertainty Fitting (SUFI-2) algorithm in the SWAT-CUP)

- For evaluation of Calibration the below methods has been chosen:
  - Graphical Procedure
  - Statistical Methods
    - Nash–Sutcliffe Efficiency (NSE)
    - Percent Bias (PBIAS)
    - And observations standard deviation ratio (RSR)

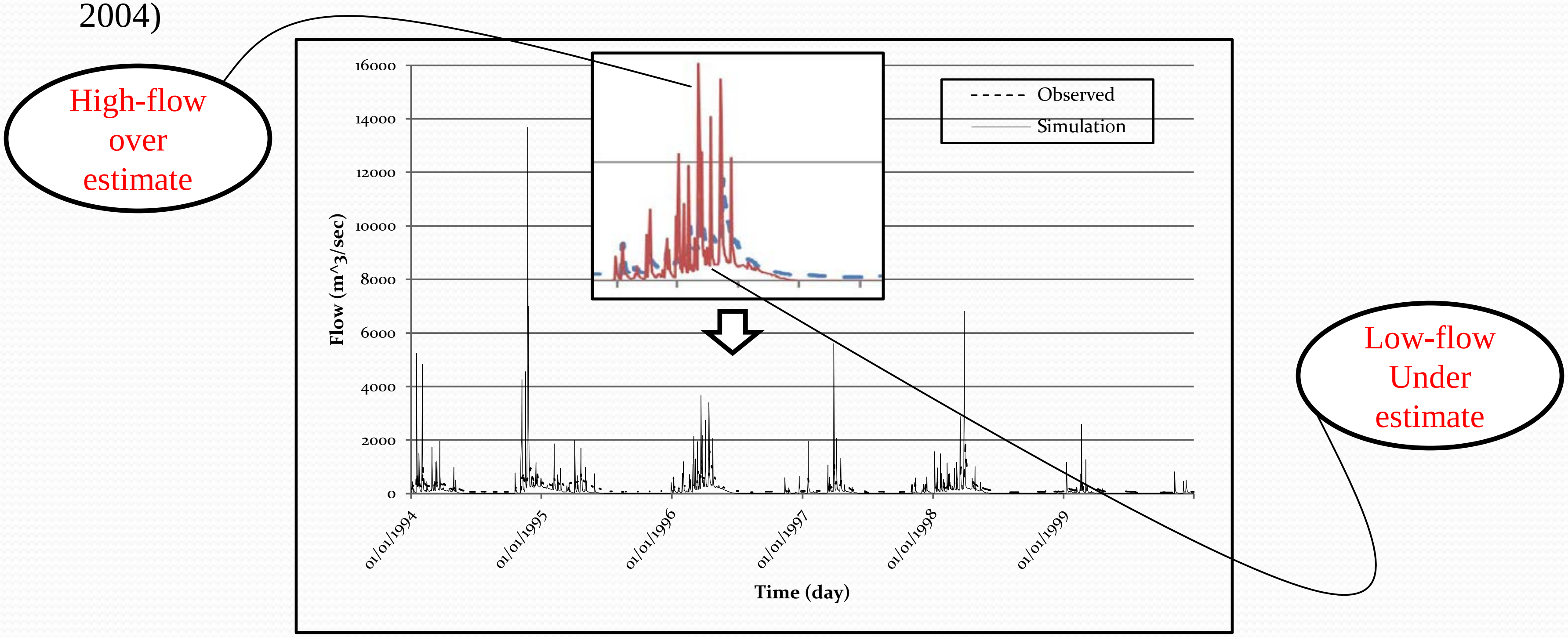
$$NSE = 1 - \left[\frac{\sum_{i=1}^{n} (Q_i^{obs} - Q_i^{sim})^2}{\sum_{i=1}^{n} (Q_i^{obs} - Q_i^{mean})^2} \right]$$

$$PBIAS = \left[\frac{\sum_{i=1}^{n} (Q_i^{obs} - Q_i^{sim}) * 100}{\sum_{i=1}^{n} (Q_i^{obs})} \right]$$

$$RSR = \frac{RMSE}{STDEV^{obs}} = \frac{\left[\sqrt{\sum_{i=1}^{n} (Q_i^{obs} - Q_i^{sim})^2} \right]}{\left[\sqrt{\sum_{i=1}^{n} (Q_i^{obs} - Q_i^{avg})^2} \right]}$$

Model Evaluation

- Graphical techniques provide visual model evaluation overviews and should be the first step in model evaluation. A general visual agreement between observed and simulated constituent data indicates adequate calibration and validation over the range of the constituent being simulated (Singh et al., 2004)

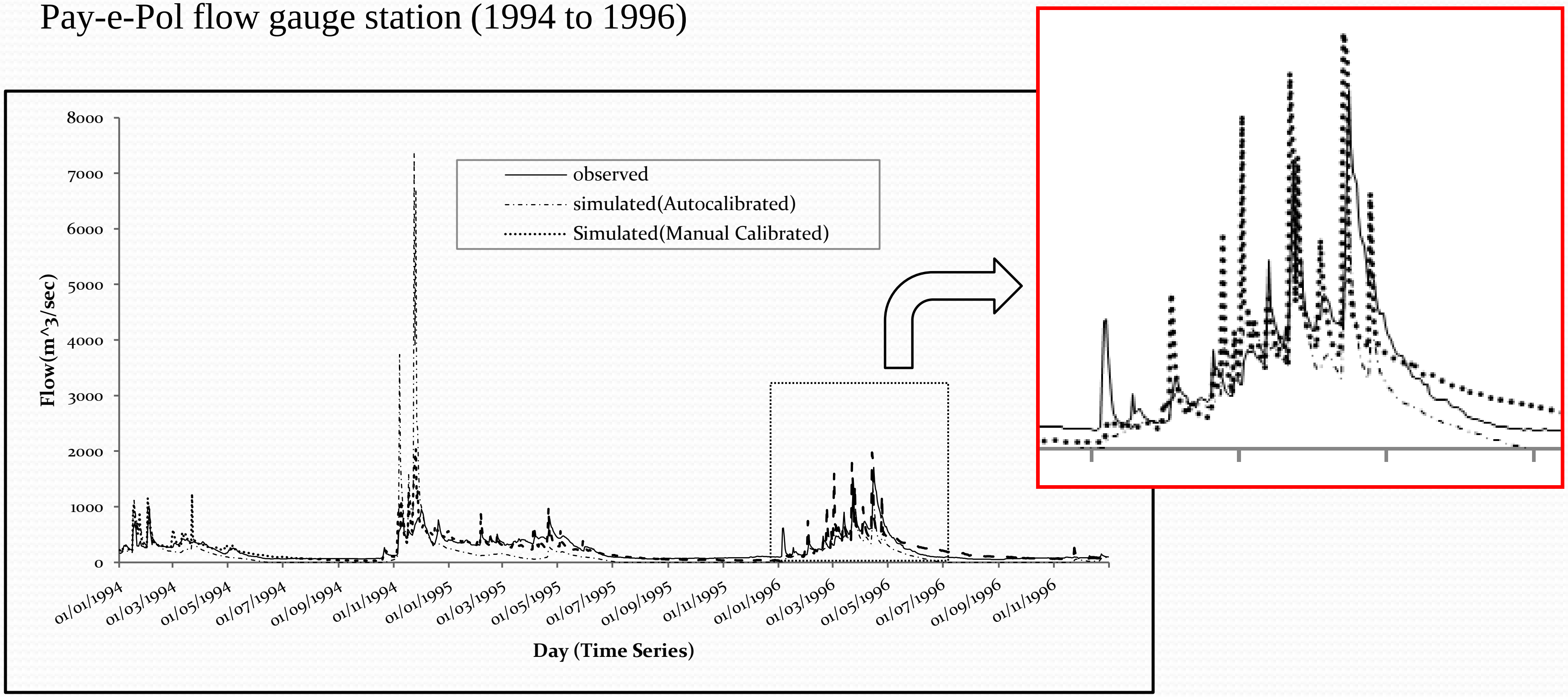


Observed and simulated flow before calibration in Pay-e-Pol flow gauge station (1994 to 1999)

(Pay-e-Pol hydrometric flow gauge located at the outlet of KARKHEH dam)

Graphical Model Evaluation

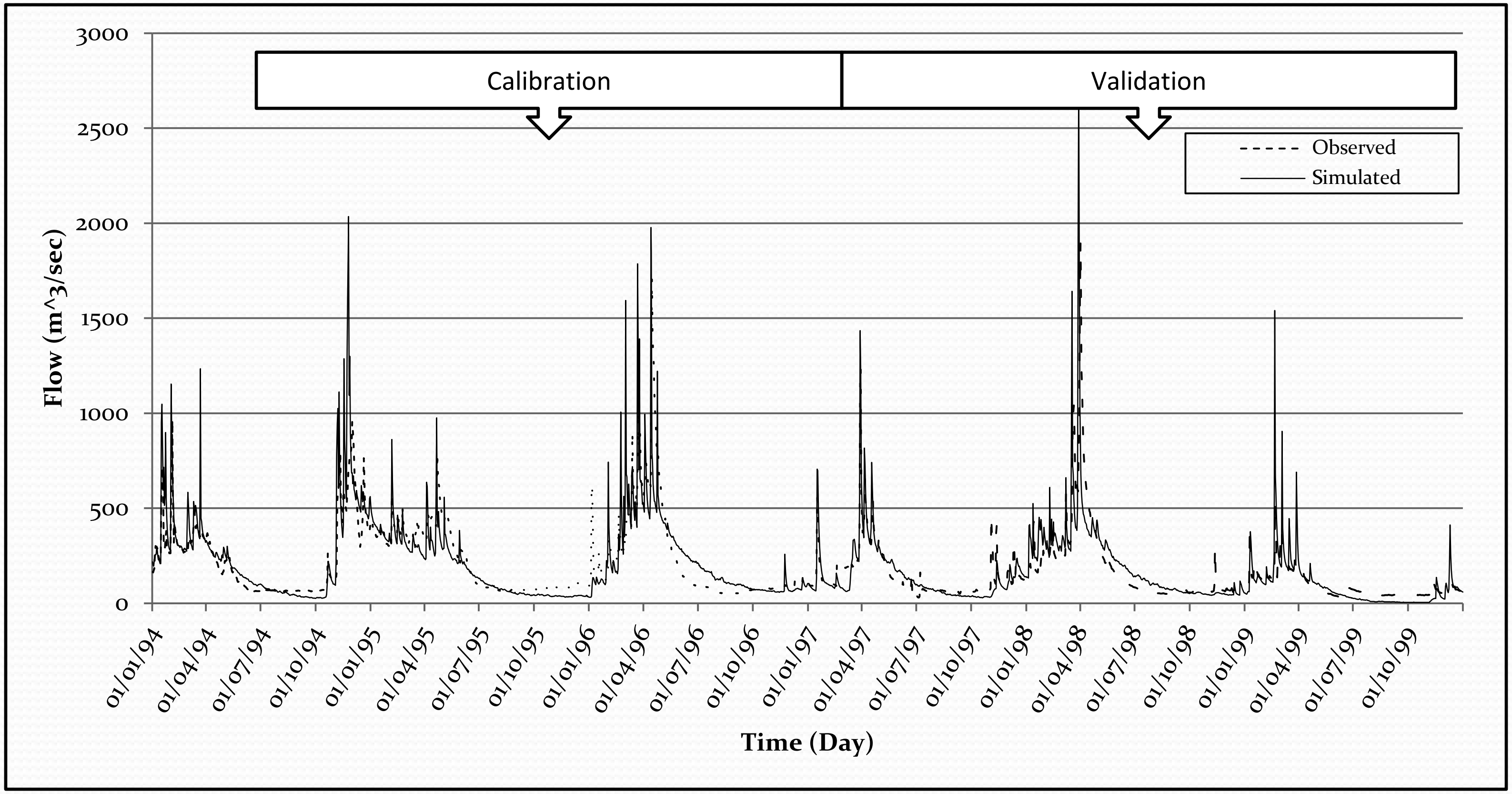
- Comparing the Observed and calibrated simulated flow (Auto-calibration and manual calibration) in Pay-e-Pol flow gauge station (1994 to 1996)



- Graphical comparison based on two approaches indicates that manual calibration method result in better simulation under extreme conditions as well as for average values

Graphical Model Evaluation

- Observed and simulated flow after manual calibration in Pay-e-Pol flow gauge station (Calibrated 1994 to 1996 and validated 1996 to 1999)



Statistical Evaluation

- A review of published literature results in the performance rating for NSE and PBIAS are expressed below

Reported performance rating for NSE

Model	Value	Performance Rating	Modeling Phase	Reference
HSPF	>0.80	Satisfactory	Calibration and validation	Donigian et al. (1983)
APEX	>0.40	Satisfactory	Calibration and validation (daily)	Ramanarayanan et al. (1997)
SAC-SMA	<0.70	Poor	Autocalibration	Gupta et al. (1999)
SAC-SMA	>0.80	Efficient	Autocalibration	Gupta et al. (1999)
DHM	>0.75	Good	Calibration and validation	Motovilov et al. (1999)[a]
DHM	0.36 to 0.75	Satisfactory	Calibration and validation	Motovilov et al. (1999)[a]
DHM	<0.36	Unsatisfactory	Calibration and validation	Motovilov et al. (1999)[a]
SWAT	>0.65	Very good	Calibration and validation	Saleh et al. (2000)
SWAT	0.54 to 0.65	Adequate	Calibration and validation	Saleh et al. (2000)
SWAT	>0.50	Satisfactory	Calibration and validation	Santhi et al. (2001); adapted by Bracmort et al. (2006)
SWAT and HSPF	>0.65	Satisfactory	Calibration and validation	Singh et al. (2004); adapted by Narasimhan et al. (2005)

[a] Adapted by Van Liew et al. (2003) and Fernandez et al. (2005).

Reported performance rating for PBIAS

Model	Value	Performance Rating	Modeling Phase	Reference
HSPF	< 10%	Very good	Calibration and validation	Donigian et al. (1983)[a]
HSPF	10% to 15%	Good	Calibration and validation	Donigian et al. (1983)[a]
HSPF	15% to 25%	Fair	Calibration and validation	Donigian et al. (1983)[a]
SWAT	<15%	Satisfactory	Flow calibration	Santhi et al. (2001)
SWAT	<20%	Satisfactory	For sediment after flow calibration	Santhi et al. (2001)
SWAT	<25%	Satisfactory	For nitrogen after flow and sediment calibration	Santhi et al. (2001)
SWAT	20%	Satisfactory	Calibration and validation	Bracmort et al. (2006)
SWAT	<10%	Very good	Calibration and validation	Van Liew et al. (2007)
SWAT	<10% to <15%	Good	Calibration and validation	Van Liew et al. (2007)
SWAT	<15% to <25%	Satisfactory	Calibration and validation	Van Liew et al. (2007)
SWAT	>25%	Unsatisfactory	Calibration and validation	Van Liew et al. (2007)

[a] Adapted by Van Liew et al. (2003) and Singh et al. (2004).

Statistical Evaluation

- Based on the Moriasi et al(2007) and Singh et al (2004); they had recommended the third value (RSR) for better performance for calibration evaluation

General performance ratings for recommended statistical parameters for a monthly time step (Moriasi et Al, 2007)

Performance Rating	NSE	PBIAS	RSR
Very good	0.75<NSE<1.00	PBIAS<±10	0.00<RSR<0.50
Good	0.65<NSE<0.75	±10<PBIAS<±15	0.50<RSR<0.60
Satisfactory	0.60<NSE<0.65	±15<PBIAS<±25	0.60<RSR<0.70
Unsatisfactory	NSE≤0.50	PBIAS≥±25	RSR≥0.70

- The next step was to calculate values for NSE, PBIAS, and RSR. With these values, model performance can be judged based on general performance ratings

Outputs for statistical parameters with manual calibration and auto-calibration at Pay-e-pol flow gauge station (Daily-Base data)

Approach	NSE		PBIAS		RSR	
	Calibration	Validation	Calibration	Validation	Calibration	Validation
Manual Calibration	**0.71** (Good)	**0.60** (Satisfactory)	**-0.24** (Very good)	**0.96** (Very good)	**0.6** (Good)	**0.25** (Very good)
Auto-calibration	**0.31** (Unsatisfactory)	**0.32** (Unsatisfactory)	**30.7** (Unsatisfactory)	**0.50** (Very good)	**0.71** (Unsatisfactory)	**0.78** (Unsatisfactory)

Statistical Evaluation

- Also it should be noted that the time step which was used for the performance analysis was daily. It was also decided to check the impact of the choice of interval on the performance of the model. Thus, performance was computed again by taking the interval as monthly and the results are shown

Outputs for statistical parameters with manual calibration and auto-calibration at Pay-e-pol flow gauge station (Using monthly data)

Approach	NSE		PBIAS		RSR	
	Calibration	Validation	Calibration	Validation	Calibration	Validation
Manual Calibration	**0.91** (Very good)	**0.85** (Very good)	**-0.001** (Very good)	**0.07** (Very good)	**0.31** (Very good)	**0.39** (Very good)
Auto-calibration	**0.31** (Unsatisfactory)	**0.32** (Unsatisfactory)	**0.002** Very good)	**0.77** (Very good)	**1.14** (Unsatisfactory)	**0.63** (Satisfactory)

- It may be observed from the above table that overall the performance with respect to all the parameters have improved by taking the monthly interval. The overall performance under the "Manual calibration" for both calibration and validation period has improved to "Very good". The results under the "Auto-calibration" approach has also improved in comparison to the daily interval for some of the individual statistical parameters, for both calibration and validation time steps. However, the overall performance under "Auto-calibration" does not improve and remain "Unsatisfactory" to be on the conservative side.

Conclusions

- Sensitivity analysis was helpful in reducing the number of parameters included in the auto-calibration and manual calibration time without seriously affecting model results
- The use of narrow ranges of variations for parameters included in auto-calibration and manual calibration affecting directly in calibration performance
- In heterogeneous basins such as KRB, based on particular climate (snow bound condition), geologic and ecologic conditions the range of variations should be wider in compare of the recommended literature results
- It has been seen that the manual calibration procedure performs much better than the auto-calibration procedure
- The performance further enhances if the calibration is done using the monthly interval rather than the daily interval

Thank you for your attention

For further questions and suggestion please contact!

E-mail: h.solaymani@civil.iitd.ac.in