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Development of Rainfall Runoff Modeling in Matlab Environment

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ABSTRACT

Background The aim of this study is to understand the basic concept and parameters of rainfall-runoff model, and how that concept applies in model as well. And familiar with how to build/develop the models of rainfall-runoff, with more about the practical situations by considering corresponding different parameters according to the seasonal conditions (for example snowfall in winter season and its role according to the temperature), hydrological conditions of site also. Matlab is used as a tool for the developing this model. This type of models are very much useful to calculate the, how much water will enter in to deeper layers of sub-soil surfaces, when rainfall occurs and to calculate the total amount water losses in different forms (for example evaporation from land and transpiration from vegetation and trees) also. Get good experience while working with Matlab to develop the individual group model and while observing the already given scrip for example model to understand as well. While working with this exercise, got good questions about concept and parameters concerned for model development and had good discussion with in the working group and with available assistance/staff.

Keywords:
Rainfall Runoff Modeling,Matlab Environment

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Introduction

Rainfall-runoff relationship is an extremely complex and difficult problem involving many variables, which are interconnected in a very complicated way. Most of the models work best when data on the physical characteristics of the watershed are available at the model grid scale (Line et al., 1997; Colby, 2001; Miller et al., 2002). This kind of data is rarely available, even in heavily instrumented research watersheds. Now Remote Sensing (RS) and Geographic Information System (GIS) make it easier to extract land surface properties at spatial and temporal scales. One of the most widely used techniques for estimating direct runoff depths from storm rainfall is the United States Department of Agriculture (USDA) Soil Conservation Service's (SCS) curve number (CN) method. Its use, however, requires a detailed knowledge of several important properties of the watershed which may not be readily available. Many researchers used information derived from satellite data and integrated them with GIS to estimate SCS CNs and runoff. Routing of runoff in river network may be undertaken using a variety of modelling procedures. The Muskingum method continues to be popular for flood routing. Muskingum routing parameters related to physical and hydraulic characteristics of channel can also be obtained using GIS technique.

Hydraulic models can simulate the changes in the water surface profiles in canals with respect to time and space. The conveyance losses can be assessed for specified surface and subsurface conditions using such models if the seepage rate is known. There are many reasons why we need to model the rainfall–runoff processes of hydrology (Fig. 1). The main reason is a result of the limitations of hydrological measurement techniques. We are not able to measure everything we would like to know about hydrological systems. We have, in fact, only a limited range of measurement techniques and a limited range of measurements in space and time. We therefore need a means of extrapolating from those available measurements in both space and time, particularly to ungauged catchments (where measurements are not available) and into the future (where measurements are not possible) to assess the likely impact of future hydrological change. Models of different types provide a means of quantitative extrapolation or prediction that will hopefully be helpful in decision making. There is much rainfall–runoff modelling that is carried out purely for research purposes as a means of formalising knowledge about hydrological systems. The demonstration of such understanding is an important way of developing an area of science. We generally learn most when a model or theory is shown to be in conflict with reliable data so that some modification of the understanding on which the model is based must be sought. However, the ultimate aim of prediction using models must be to improve decision making about a hydrological problem, whether that be in water resources planning, flood protection, mitigation of contamination, licensing of abstractions, or other areas. With increasing demands on water resources throughout the world, improved decision making within a context of fluctuating weather patterns from year to year requires improved models. Rainfall–runoff modelling can be carried out within a purely analytical framework based on observations of the inputs to and outputs from a catchment area. The catchment is treated as a black box, without any reference to the internal processes that control the transformation of rainfall to runoff.

Materials and Methods

Firstly the description is about materials used for this exercise and sources for those materials are given below, under materials.

- A zip folder called, RunoffExcrise.zip is downloaded from Blida (www.bilda.kth.se) with all necessary files in it.
- Instruction manual.
- Matlab software: It is (matrix laboratory) a high level computing language and interactive environmental for algorithm development, data visualization, and numerical computing.
- HBV-VS model.
- The study area is located at costal forest of Forsmark, and it is 100 km north of Stockholm.
- Hydrological data: in general the data regarding to water movement on the earth is called as hydrological data. For example (the data like precipitation, water tem-

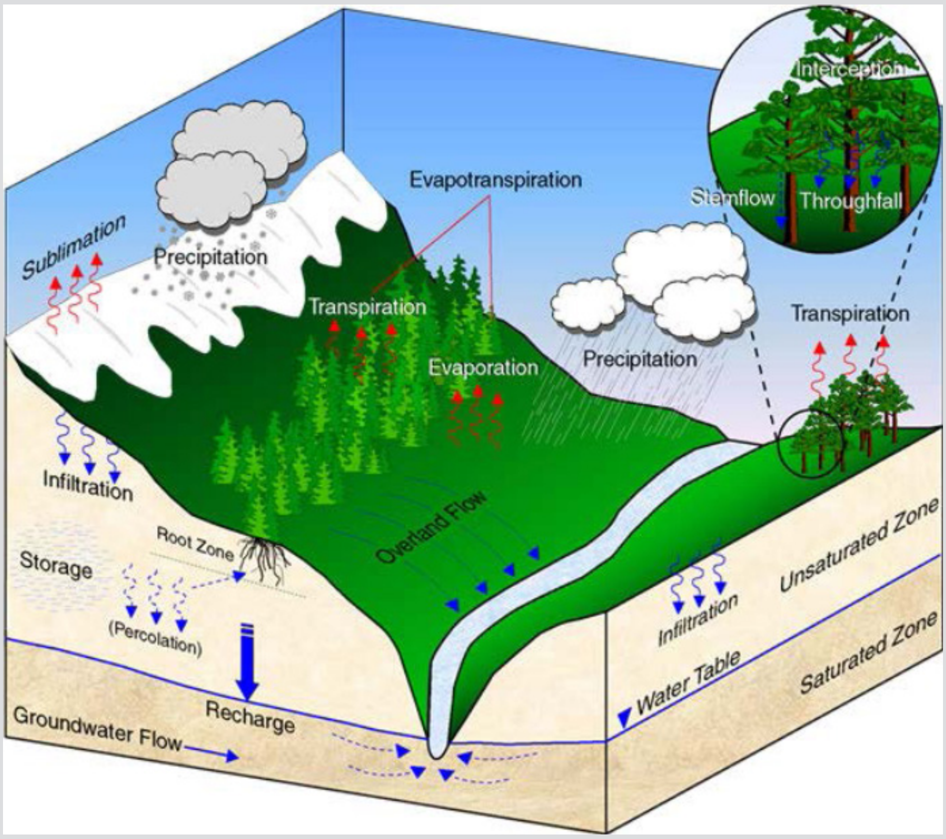

Fig. 1 Hydrological water budget

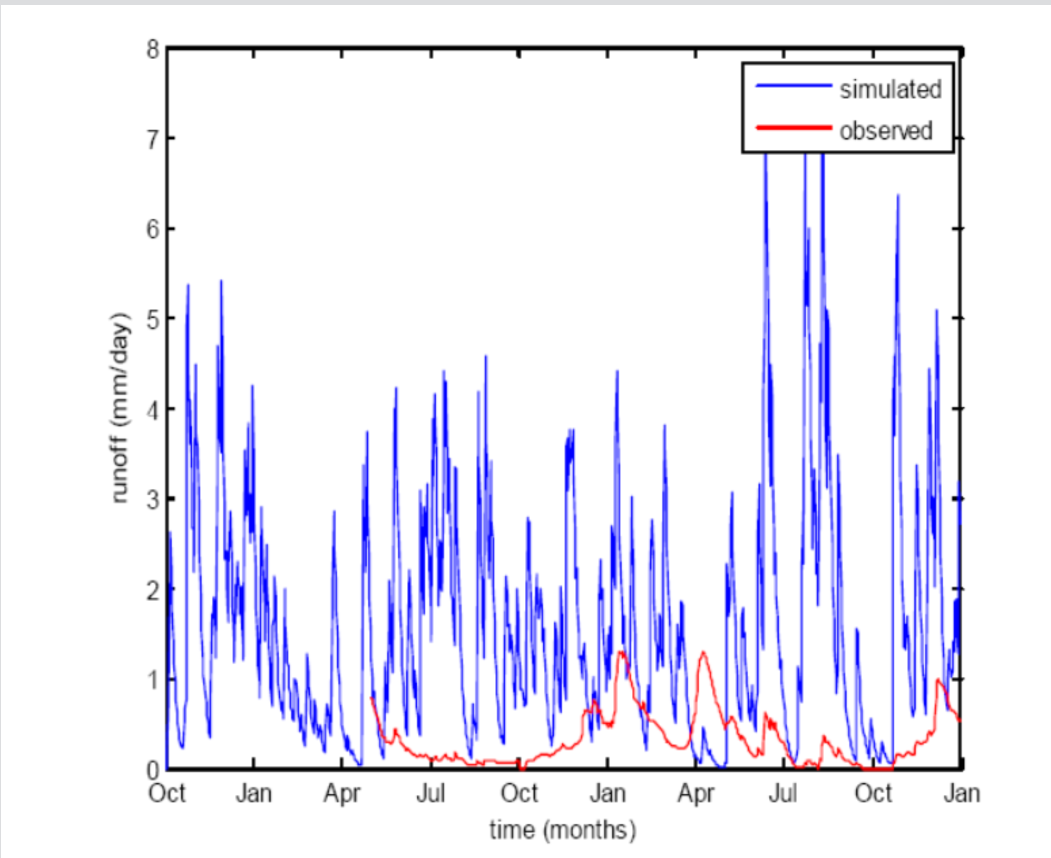

Fig. 2 Simulated and observed runoff

perature, stream flow and etc..,)

- Snow fall data.
- Meteorological data: The data regarding to atmosphere of different parameters like (wind speed, temperature and etc..,)
- Hydrological properties/conditions of the sight as well.

This total study has three tasks/sessions, and each task is separately described with point wise experiences are as follows.

Task 1: The intension of the task one is to become familiar with mat-lab. How to start it, and to know how to write/give commands, and how to write the script in mat-lab language.

- The zip folder (RunoffExercise.zip) is downloaded from the Bilda to my working directory.
- Started the mat-lab from main menu of my desktop and find the different windows (like command window, current folder and workspace etc..,)
- Getting to know what happen with different commands (like save (>>save myworkspace.mat), load (>>load myworkspace.mat) and clear etc..,
- Get to know the some data types of matlab. For example (Scalars, matrices and arrays).
- Also know that the essential elements of matlab are functions and scripts.

Task 2: The main purpose of this task is to work with example model which has been already written by “David Gustafsson”. To work on it and getting familiar with model.

- File “rnuoffmodel.m” contained simple example of rainfall-runoff model implemented as a mat-lab function.
- Detailed study of mat-lab script that illustrated in run_simulation.m, for this the data has been used from forsmark catchment in mid Sweden. Results are seen by visualization of mat-lab plot commands (>> run_simulation).
- After this runoff model file has been opened in mat-lab editor, to study the structure of function, the comments were started with (%) this symbol and in green color.
- The important things observed were input and output arguments, variables (like storage, flows, model parameters and meteorological input data.) and time-step loop.
- The answers for the questions in this task were described in the results and discussion section.
- This command was used (>> run_simulation) to run the model. In results, there were two lines representing (one with simulated values and other with observed values) as shown in the following diagram (Fig. 2).
- This is the output of an example model given in the file and the results showing the bad interruption of simulated verses observed data in the below shown graph.

Task 3: The aim of this task was to develop the model with considering the missing factors in the existing model as per the assumptions and parameters considered by the developer.

- By considering the conditions/factors according to winter season and summer season (like when the air temperature is less than “Zero” precipitation will become snowfall, and this snow fall was stored on the land surface.)
- In summer season/when the temperature rises more than “Zero”, it starts melting and reaches to unsaturated soil zone.
- From starting of the summer season due to the temperature, the snow storage starts melting and if the precipitation also happened then both of the sources will be added to the unsaturated soil zone.
- The above mentioned two conditions were written in “if loop” function in developed model of rainfall runoff model. To get the accuracy in output of the model according to the outside conditions of provided data.

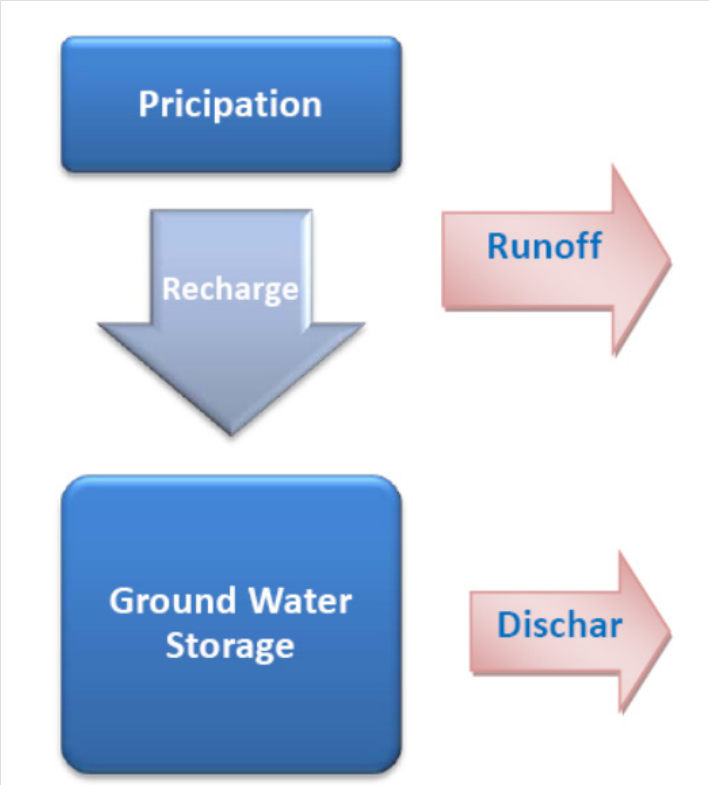

Fig. 3 Flow chart of example model

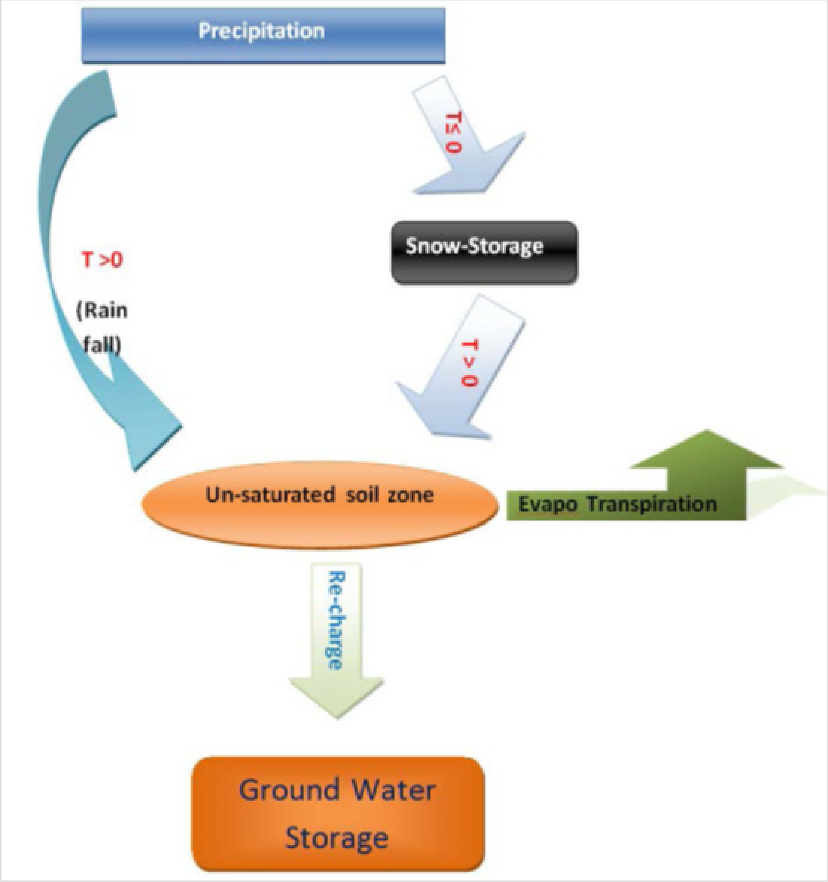

Fig. 4 Developed rainfall-runoff model with all parameters

- The equation for unsaturated zone was given (inflow=(precipitation/rain)+Melt)
- The field capacity (FC) is the maximum capacity of unsaturated zone water capacity.
- When the capacity of unsaturated zone limit exceeds the water flows from unsaturated soil zone to ground water table.
- This water movement was shown as the “recharge” to the ground water table in the flowchart number 2.
- The equation representation for the recharge as follows R=Su-FC.
- Before this process is going to take place there were one more losses, it was evapotranspiration. Evaporation forms the unsaturated soil zone and transpiration from the vegetation on unsaturated soil zone.
- This was calculated as following ET=(Su/FC)*PET. In above equation the term PET represents “potential evapotranspiration” and this data is given in the formarkdata.txt

Results and Discussion

1) No, the simulated discharge was not equal to the observed discharge, because no data availability of snow fall and temperature variation.

2) The example model which was observed from the rumoffmodel.m file and described in my own view as followed.

The different (Storage, Flow, Input, and Model) variables/parameters were observed and listed below.

- Storage Variable: Ground Water
- Flow Variables: Recharge, Discharge.
- Model Parameters: Runoff Coefficient, Discharge Coefficient, and Initial Ground Water.
- Input Variable: Precipitation.

Recharge = recharge coefficient *precipitation.

Discharge = discharge coefficient * storage.

Ground-water storage = ground water storage + (recharge – discharge) * time steps.

3) The answer for >>testvar = rmse (F (:, 2), qobs) was 0.3711.

RMSE= $\sqrt{\frac{\sum r_i^2}{n}}$ where RMSE= Root mean square error, r=residual& n=total number of values

4) Function for (ME) mean error. ME (mean error = (Qobs – Qsim)/length (Q), where Qobs and Qsim are the vectors containing corresponding observed and simulated daily discharge data according to the time serious “T” respectively. The answer for ME was -0.1578. Difference between RMSE and ME? RMSE: it is always positive (+ve) and it is an absolute value of error. ME: it can be positive or negative as well. In this case ME is negative (-ve), because the simulated discharge values were higher than the observed ones. It is only mean of errors.

5) The function for Nash-Sutcliff model efficiency Ens was

Ens = 1 – (sum ((Qobs – Qsim). ^2)/sum ((Qobs – mean (Qobs)). ^2)).

The calibrated value with this model for the example model was -6.5109. Had god discussion about this output value and model, understand that it is not a good model to calibrate.

6) The file calibrationfunction.m has opened to understand objective function, famine search function and procedure as well. The model parameters are changed as the initial variables. The model results are changed moderately by changing parameters, but our group feels that not optimum level. The model has to improvements some more according the real world conditions. Our group tries to bring/modify the model more optimistic to the real world, as per our assumptions in parameters and its values as well.

7) By changing the parameters manually, our group interrupted the ME (mane), RMES (Root Mean Square Error), and ENS Nash-Sutcliff model efficiency. The parameters considered are runoff coefficient, Discharge coefficient and Storage. The results are given below.

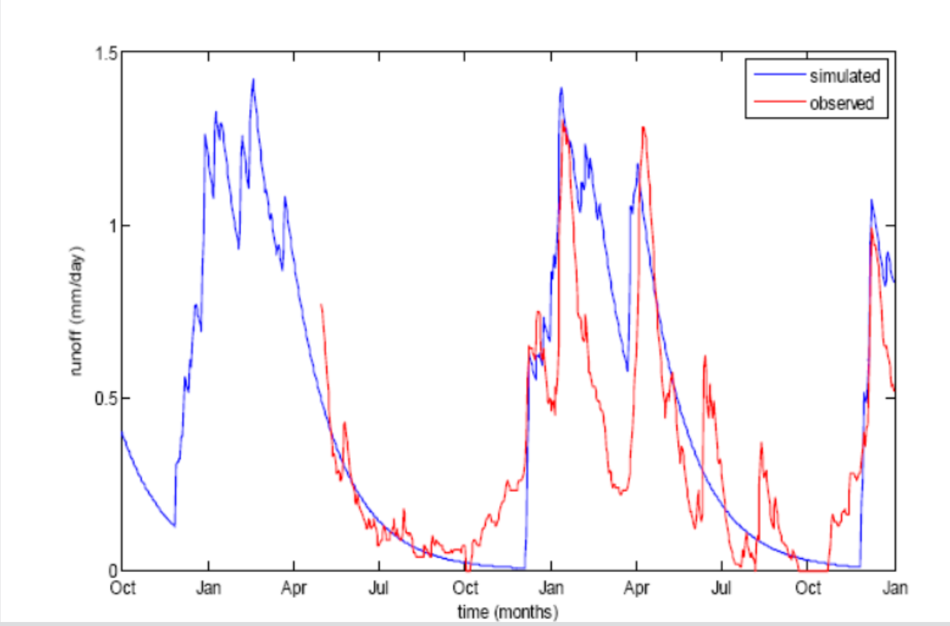

Fig. 5 Developed model interpretation

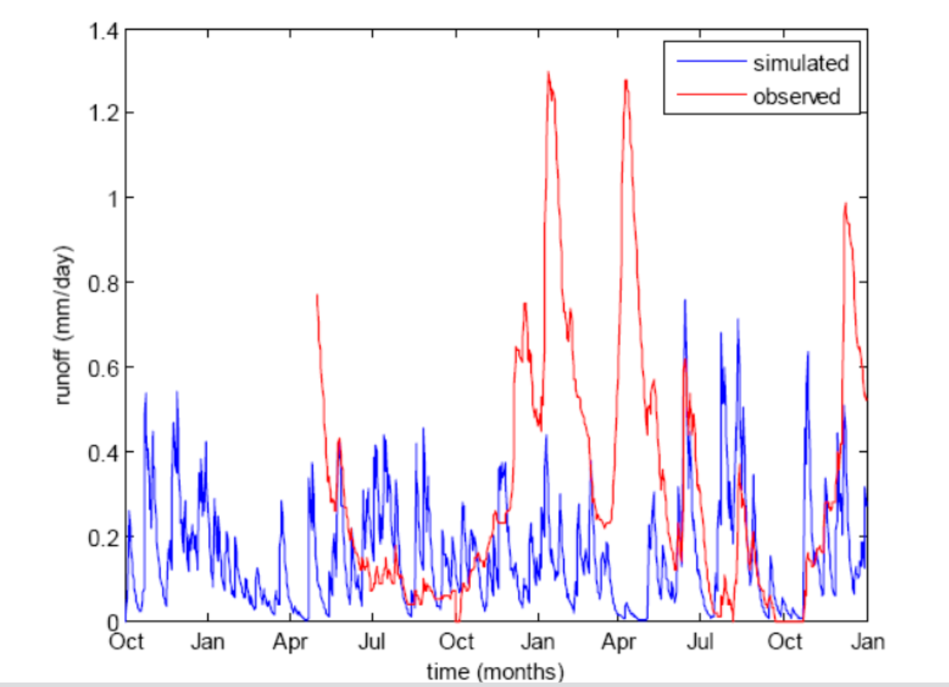

Fig. 6 Simulated and observed runoff values during calibration

Table 1 Parameter values to calibrate three methods and its results

Parameters				Results		
Sl. No.	Runoff co-efficient	Discharge coefficient	Storage	Mean	RMES	Nash-Sutcliff efficiency
1	1	1	1	-0.158	3.6325	1.2865
2	0.5	0.5	0.2	0.4822	1.2165	-0.3013
3	0.5	0.5	0.1	0.4822	1.2165	-0.3013
4	1	0.5	1	0.0015	0.3644	-2.5973

Form the above results, there is no much /not at all any difference in output results in calibration of different methods in second and third assumption of parameters. The mean and RMES are near to good, for the above mentioned parameter values consideration in fourth assumption. But the Nash-Sutcliff model sows still not good results.

8) The model performance is not at optimum level. But it is good model for the assumption and represents basic system. As per our group discussion, the current model structure is not good enough to represent the real system/real world.

9) The key processes missing are snow fall and snow storage, when the temperature is less than or equal to zero (0).

- The clear description about the seasonal difference in processes taking place is mentation in the task 3 of methods session.
- The total processes as per our group assumptions and how can take place in the real world is given in detail below.
- This is flowchart represents the modified model.

10) The developed model by considering possible parameters was below

The parameters assumed for our group won model and the graphical representation of results are given below

- Field Capacity FC = 250
- Discharge coefficient = 0.02
- Discharge_exp = 1
- Melt coefficient = 2
- Initial ground water = 20
- Snow storage = 0
- Su = 0.5 * FC.

By considering the above parameters the interruption of simulated verses observed data are given below graph.

This is the interpretation of the observed verses simulated data while calibrating the model with different parameters values.

Conclusions

In this study rainfall-runoff model was developed successfully with the consideration of many parameters such as field capacity, discharge coefficient, discharge_exp, melt coefficient, initial ground water and snow storage. The simulated and observed runoff were plotted and visualized during calibration and validation periods.

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