Estimation of reservoir inflow in data scarce region by using Sacramento rainfall-runoff model – A case study for Sittaung River Basin, Myanmar

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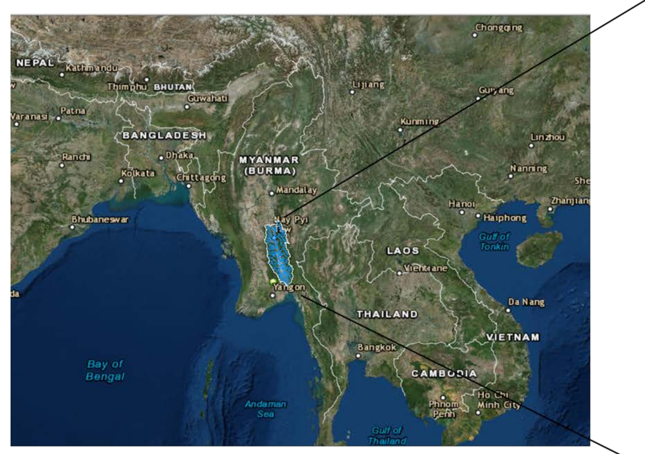
Background

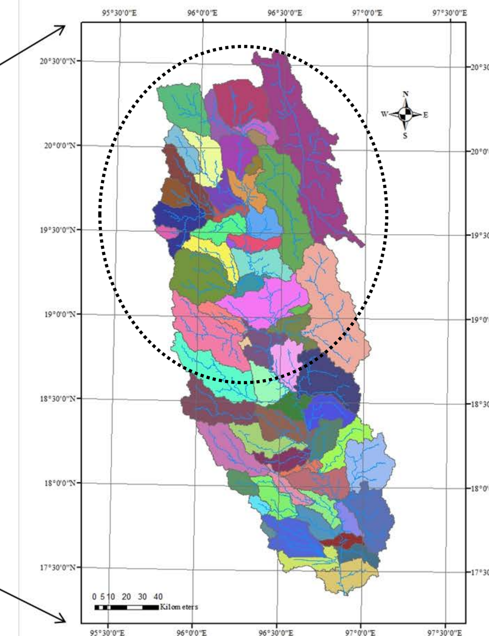
The Sittaung River is one of four major rivers in Myanmar. At present, more than 20 reservoirs have already been constructed in this river basin for multiple purposes such as irrigation, domestic water supply, hydropower generation, and flood control. The estimation of reservoir inflow is essential for the operational management of a reservoir system.

The Sacramento soil moisture accounting model (SAC-SMA) is used in this study. The main objectives are to investigate the applicability of satellite rainfall data in data scare region and to assess the improvement of model performance by using distributed rainfall in a catchment.

Moreover, a real time control system is being developed for Sittaung River Basin by using Model predictive control. Therefore, the Sacramento model outcomes can be used as input data for real time control system.

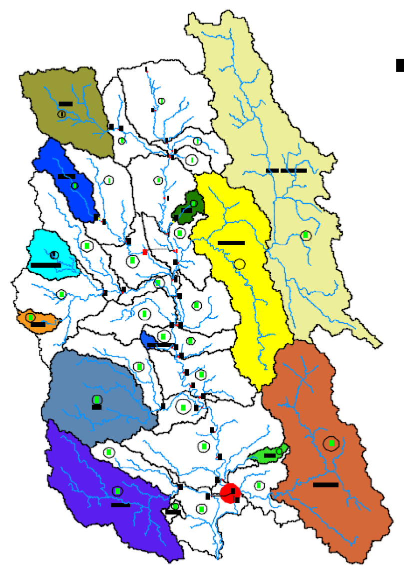
Study area





Sittaung River Basin, Myanmar

Material & Method



- Upper part of Sittaung river basin

  Numbers of sub catchments: 31

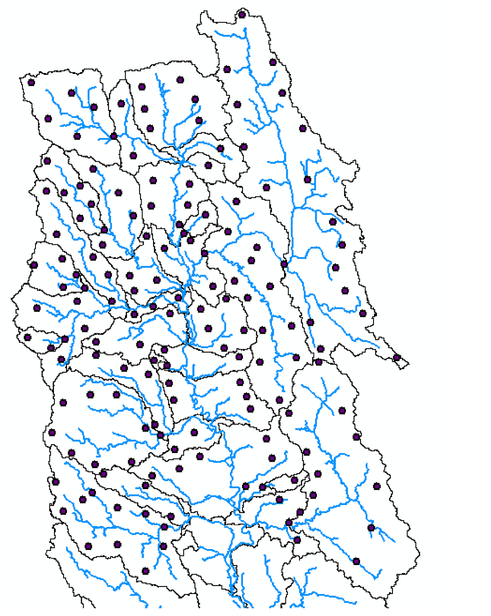
  Numbers of Reservoir: 12

  Total catchment area = 19,244 km^2

  Catchment area cover

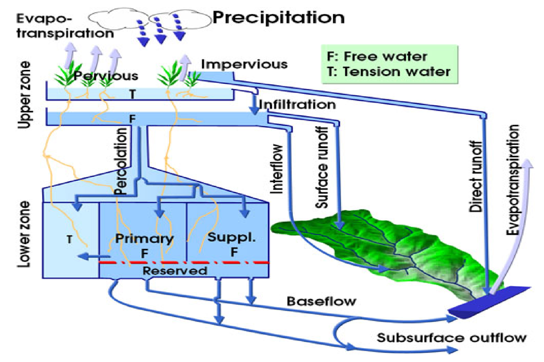
  by reservoirs = 10,759 km^2

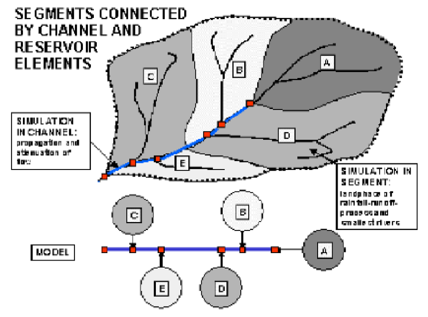
Three hourly TRMM (3B42) rainfall data is used to estimate the inflow to the reservoir due to the lack of observed data in the drainage basin. The observed rainfall data is only available at reservoir site with daily time scale. This map shows distributed rainfall inputs over the catchments.



Material and method

The Sacramento model is used to transform the rainfall to runoff through two soil zones; upper zone and lower zone [1]. Each zone has two water components; free water and tension water. Soil moisture depletion and replenishment in the storage are determined based on precipitation, evapotranspiration, percolation and horizontal outflow. The conceptual diagram of the SAC-SMA is shown in figure [2].





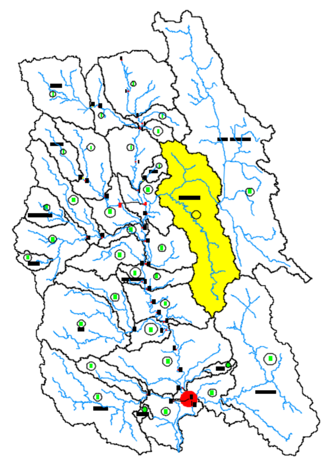
The SOBEK , an integrated software package for 1D-2D flow simulation, is used to model a water system coupling with SAC-SMA modules [3]. The application of the SAC-SMA model in SOBEK is based on a distributed approach. For the large catchment, it can be divided into a number of sub- catchments and then it can be linked to a channel.

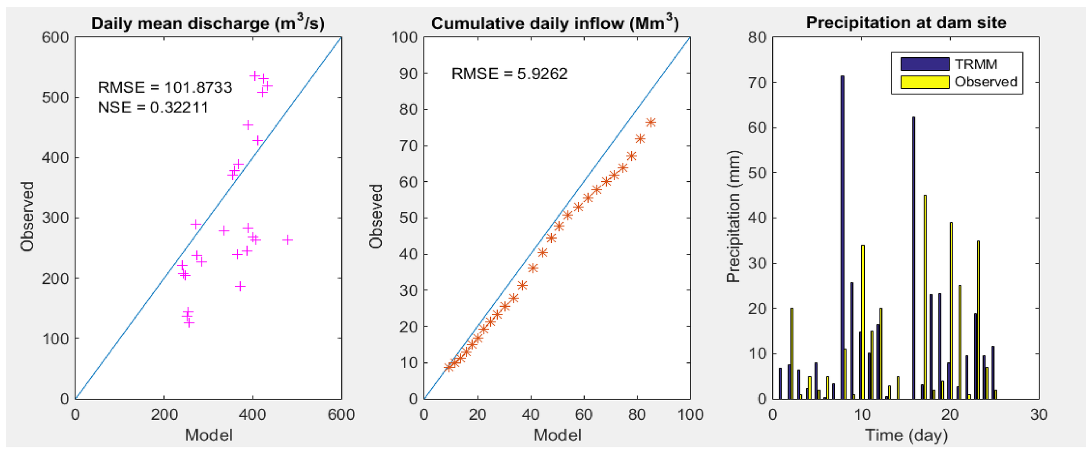
Sacramento model parameters used for simulation

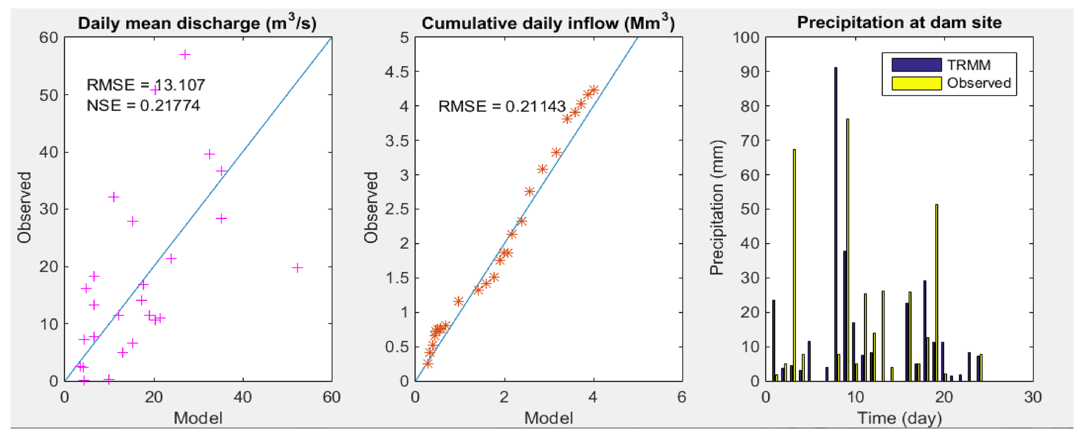
No.	Parameter	Description	Used for model	Acceptable Range
1	UZTWM	The upper layer tension water capacity, mm	70	10-300
2	UZFWM	The upper layer free water capacity, mm	150	5-150
3	UZK	Interflow depletion rate from the upper layer free water storage, day^{-1}	0.1	0.10-0.075
4	ZPERC	Ratio of maximum and minimum percolation rates	10	5-350
5	REXP	Shape parameter of the percolation curve	2	1.0-5.0
6	LZTWM	The lower layer tension water capacity, mm	500	10-500
7	LZFSM	The lower layer supplemental free water capacity, mm	300	5-400
8	LZFPM	The lower layer primary free water capacity, mm	550	10-1000
9	LZSK	Deplection rate of the lower layer supplemental free water storage, day^{-1}	0.01	0.01-0.35
10	LZPK	Deplection rate of the lower layer primaryl free water storage, day^{-1}	0.001	0.001-0.05
11	PFREE	Percolation fraction that goes directly to the lower layer free water storage	0.2	0.0-0.8
12	PCTIM	Perment impervious area fraction	0.024	Not given
13	ADIMP	Maximum fraction of an additional area due to saturation	0.2	Not given
14	RSERV	Fraction of lower layer free water not transferable to lower layer tension water	0.3	Not given

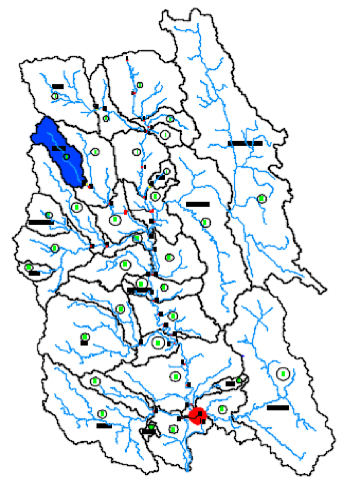
Result and Discussion

The model is simulated with hourly time step and the simulation period is one month. Then, the model is calibrated with available observed data for some catchments. The first calibration results are shown in this section.

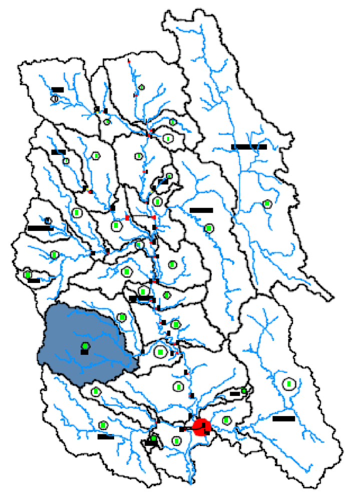


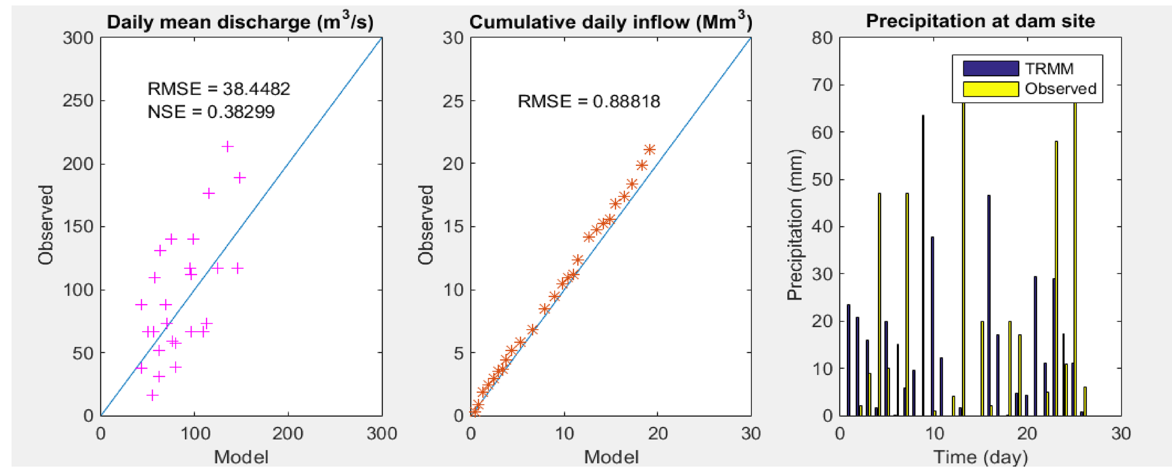


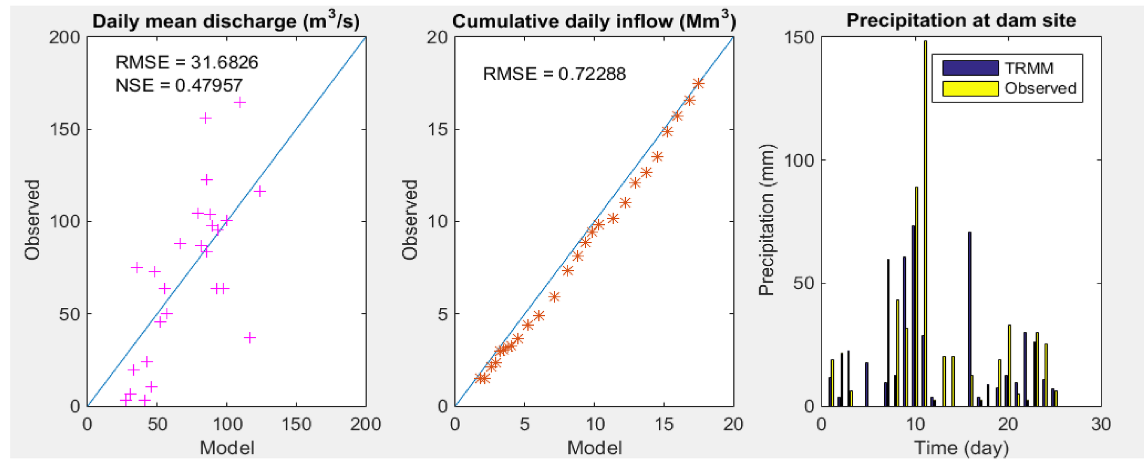


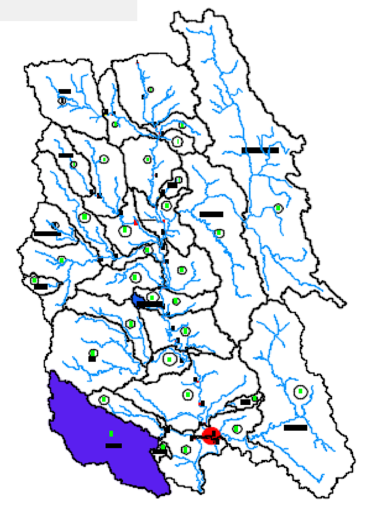


Result and Discussion

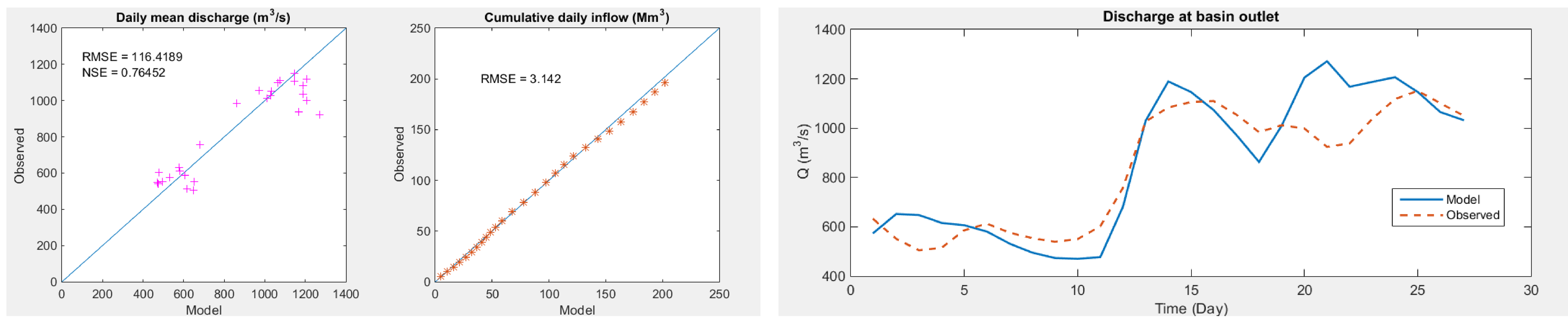








The rainfall analysis indicates that the correlation between TRMM and observed data is very low and TRMM cannot capture high rainfall amount at dam site. The Nash-Sutcliffe Efficiency (NSE) coefficients are very low when the observed runoff data contains large outliers in it. There are uncertainties associated with the rainfall data, and the measured point rainfall data are available only at limited locations. As the RMSE values, the prediction errors are high for daily mean discharge, however, the cumulative inflows are similar to observed data.



The scatter plot compares the model and observed daily runoff over the simulation period for the 31 sub-catchments at outlet point on main river. The NSE value at basin outlet is larger than 0.5 even though the NSE values of sub-catchments are less than 0.5. As the results, the inflow estimation for large catchment is more better because large catchments require more rainfall stations to adequately capture the spatial rainfall variability than small catchments.

Next steps

- The longer time series will be used for calibration of model parameters and also for validation.
- Investigate if model prediction errors can be reduced by differentiating parameters for different catchments
- Investigate possibilities to correct TRMM rainfall and improve temporal interpolation to one hour timescale

References

[1] Vrugt, J.A., Gupta, H. V., Dekker, S.C., Sorooshian, S., Wagener, T. and Bouten, W. 2006. Application of stochastic parameter optimization to the Sacramento Soil Moisture Accounting model. Journal of Hydrology. 325, 1–4 (2006), 288–307.

[2] Picture: http://ldas.gsfc.nasa.gov/nldas/images/SAC_schematic.jpg,

[3] Sobek User Manual, https://content.oss.deltares.nl/delft3d/manuals/SOBEK_User_Manual.pdf

[4] Tropical Rainfall Measuring Mission (TRMM), TRMM (TMPA) Rainfall Estimate L3 3 hour 0.25 degree x 0.25 degree V7, https://disc.gsfc.nasa.gov/datacollection/TRMM_3B42_7.html