Evaluation of SWAT Auto-calibration using Diverse Efficiency Criteria

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Introduction

Advances in Geosciences

Comparison of different efficiency criteria for hydrological model assessment

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SWAT model application i

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1. Introduction

In recent years, application of models ha
able tool for the understanding of the natu
at the watershed scale. Watershed models
number of parameters (Sorooshian et al., 1
of such comprehensive models requires a
resources (funds, observed data, time, exp
often unavailable in developing countries
Whilst researchers in the developed countr
gauged catchments where new models can
al., 2005; Yapo et al., 1996), their counterp
countries are forced to apply the models in
(Ndomba et al., 2005; Mulungu and Munisi
A comprehensive, complex hydrologic m
ized by a multitude of parameters (Eckha
Due to spatial variability, measurement er
many of the required parameters will not

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changes and hydropower
Rhine basin

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erlands

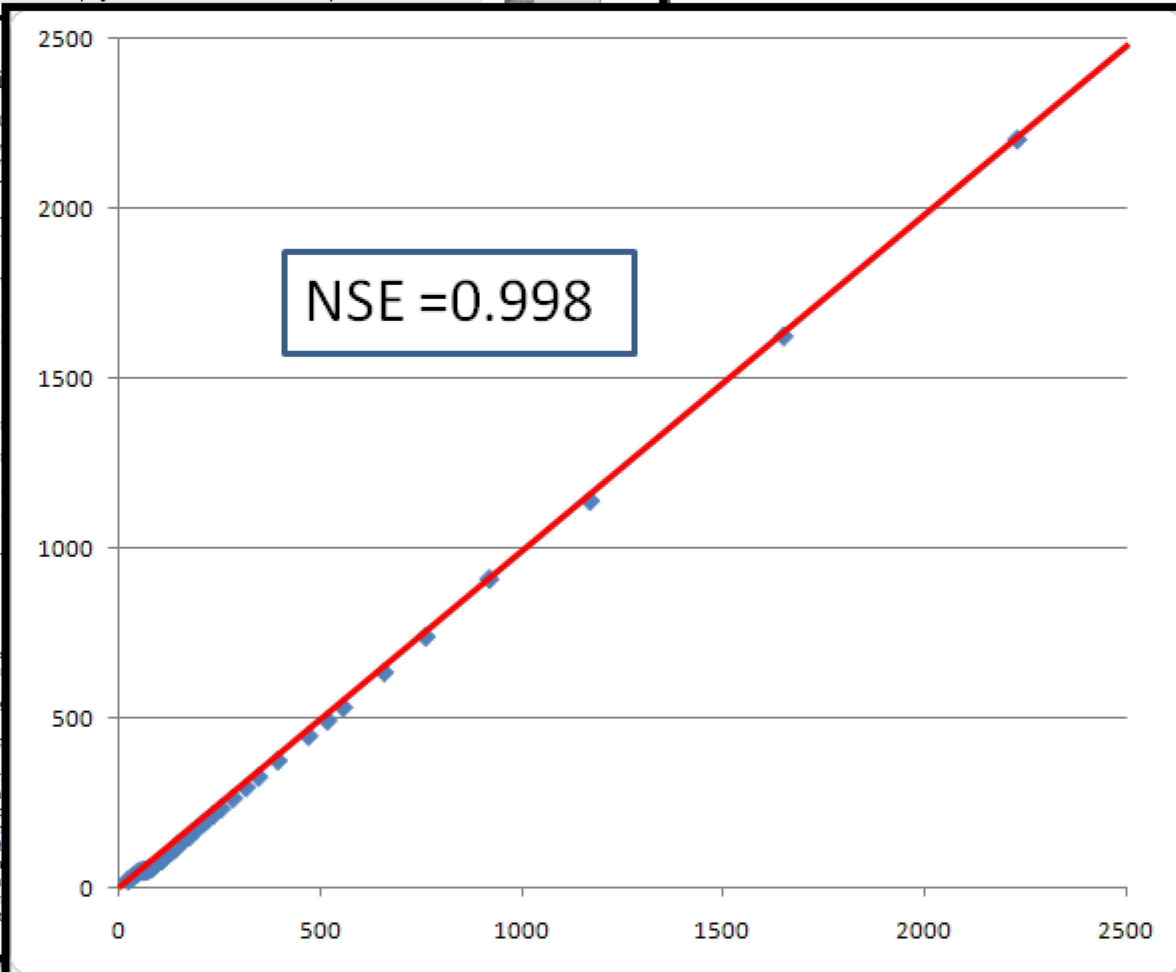
2005

the Swiss Alpine Rhine basin (4108 km²) have been
distributed hydrological catchment model WaSiM-
e of 500 m × 500 m and a temporal resolution of 1 h.
ges on the hydrology in a subcatchment of the Swiss
d urbanization-afforestation scenario. Furthermore, a
othetical change from pastures into forests.
the influence of reservoirs. In particular, a significant
ow-flow periods in winter. Further, reservoirs function
g reservoir level data, an attempt has been made to
drological modeling. Results show a clear increase in
of the land cover change scenarios using WaSiM-ETH
ts, while its effect is negligible further downstream.
tion, especially at the valley bottom. Consequently,
. This decline in runoff is dependent on the decrease

; Urbanization; Afforestation

roduction

nomic and demographic growth, increasing
of life and, consequently, higher electricity de-
, and the rationalisation and intensification of



and protection of Europe's aquatic environment. The principal objective of the WFD is to achieve good chemical and ecological status for receiving waters by 2015, and mandates Member States to develop river basin management schemes. This planning mechanism is intended to ensure integrated management of the river environment, providing a decision-making framework for setting environmental objectives. However, the management of water quality from non-point sources would require very expensive monitoring efforts.
Mathematical modeling is a necessary step in the implementation

Because of the complexity of the hydrologic processes, hydrologic-based, distributed parameter models and GIS constitute a powerful combination for water quantity and quality assessment [4,5]. There are several reasons that enforce the combination of the aforementioned models with GIS for water resources management, the most important of which are [6]: the automation of data input and output in the pre- and post-processing stage of model development, as well as the ability to develop interactive post-processing tools that provide the opportunity for easier understanding of hydrologic system function; and, the

❑ Introduction

Soil and Water Assessment Tool (SWAT)

❑ Introduction

Calibration SWAT model

Calibration of model through adjusting input parameter. (Manual calibration)

Introduction

Calibration SWAT model

Au Tool

F rs

Introduction

Parameter Solution (Parasol) Method

Finds the best parameter

Based on Shuffle Complex Evolution(SCE-UA)

Introduction

Root Mean Square Error(RMSE)

Coefficient of Determination (R^2)

Index of agreement *d*

Modified NSE and *d*

Relative efficiency criteria NSE and *d*

❑Objectives of study

- Modification of SWAT Auto-calibration using different efficiency criteria.

- Comparison of each SWAT Auto-calibration and finding the efficiency criteria which make the better calibration result.

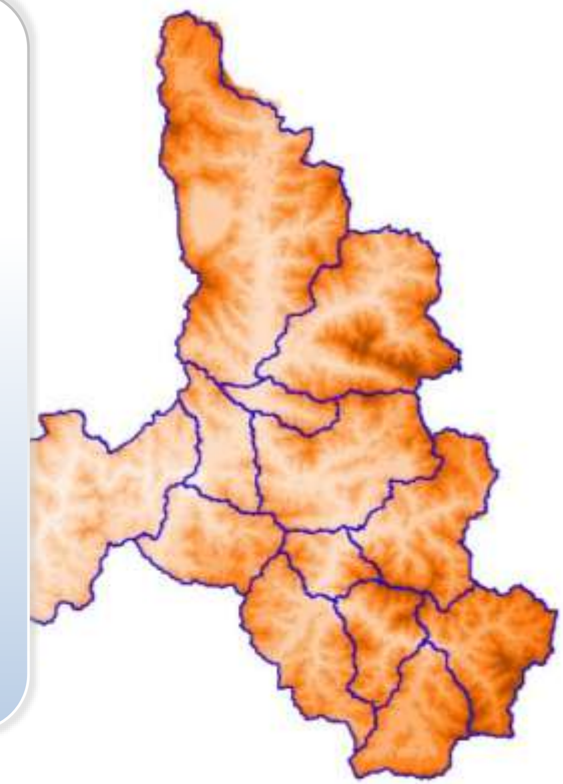
❑Study Area

Soyanggang dam watershed

Area: 2,703 km^2

Forest : 89.6 %

Agricultural area : 5.3 %



Efficiency criteria

Nash-Sutcliffe Model Efficiency Coefficient (NSE)

$$NSE = 1 - \frac{\sum_{i=1}^{n} (O_i - S_i)^2}{\sum_{i=1}^{n} (O_i - \overline{O})^2}$$

S_i = Simulated data

O_i = Observed data

$\overline{O}$ = The average of observed data

여기에 수식을 입력하십시오.

Efficiency criteria

NSE with logarithmic values

$$\ln NSE = 1 - \frac{\sum_{i=1}^{n} (\ln O_i - \ln S_i)^2}{\sum_{i=1}^{n} (\ln O_i - \ln \overline{O})^2}$$

S_i = Simulated data

O_i = Observed data

$\overline{O}$ = The average of observed data

Using to overcome oversensitivity to extreme values

❑ Efficiency criteria

Index of agreement d (Willmot, 1981)

$$d = 1 - \frac{\sum_{i=1}^{n}(O_i - S_i)^2}{\sum_{i=1}^{n}\left(\left|S_i - \overline{O}\right| + \left|O_i - \overline{O}\right|\right)^2}$$

S_i = Simulated data

O_i = Observed data

$\overline{O}$ = The average of observed data

Using to overcome insensitivity of NSE and R^2

❑ Efficiency criteria

Modified forms of NSE and *d*

$$NSE_m = 1 - \frac{\sum_{i=1}^{n} |O_i - S_i|}{\sum_{i=1}^{n} |O_i - \overline{O}|}$$

$$d_m = 1 - \frac{\sum_{i=1}^{n} |O_i - S_i|}{\sum_{i=1}^{n} \left(|S_i - \overline{O}| + |O_i - \overline{O}| \right)}$$

Same purpose logarithmic NSE and Index of *d*

Efficiency criteria

Relative efficiency criteria NSE and *d*

$$NSE_{rel} = 1 - \frac{\sum_{i=1}^{n}\left(\frac{O_i - S_i}{O_i}\right)^2}{\sum_{i=1}^{n}\left(\frac{O_i - \bar{O}}{\bar{O}}\right)^2}$$

$$d_{rel} = 1 - \frac{\sum_{i=1}^{n}\left(\frac{O_i - S_i}{O_i}\right)^2}{\sum_{i=1}^{n}\left(\frac{\left|S_i - \bar{O}\right| + \left|O_i - \bar{O}\right|}{\bar{O}}\right)^2}$$

More sensitive in particular during low flow conditions

Methods

The objective function of current SWAT Auto-calibration

Sum of the squares of the residuals(SSQ)

❑ Methods

$$NSE = 1 - \frac{\sum_{i=1}^{n}(O_i - S_i)^2}{\sum_{i=1}^{n}(O_i - \overline{O})^2}$$

SSQ

Fixed

Methods

NSE with logarithmic values

$$\ln NSE = 1 - \frac{\sum_{i=1}^{n} (\ln O_i - \ln S_i)^2}{\sum_{i=1}^{n} (\ln O_i - \ln \bar{O})^2}$$

Index of agreement *d*

$$d = 1 - \frac{\sum_{i=1}^{n} (O_i - S_i)^2}{\sum_{i=1}^{n} (|S_i - \bar{O}| + |O_i - \bar{O}|)^2}$$

Modified forms of NSE

$$NSE_m = 1 - \frac{\sum_{i=1}^{n} |O_i - S_i|}{\sum_{i=1}^{n} |O_i - \bar{O}|}$$

Modified forms of *d*

$$d_m = 1 - \frac{\sum_{i=1}^{n} |O_i - S_i|}{\sum_{i=1}^{n} (|S_i - \bar{O}| + |O_i - \bar{O}|)}$$

Methods

Relative efficiency criteria NSE

$$NSE_{rel} = 1 - \frac{\sum_{i=1}^{n}\left(\frac{O_i - S_i}{O_i}\right)^2}{\sum_{i=1}^{n}\left(\frac{O_i - \bar{O}}{\bar{O}}\right)^2}$$

Relative efficiency criteria d

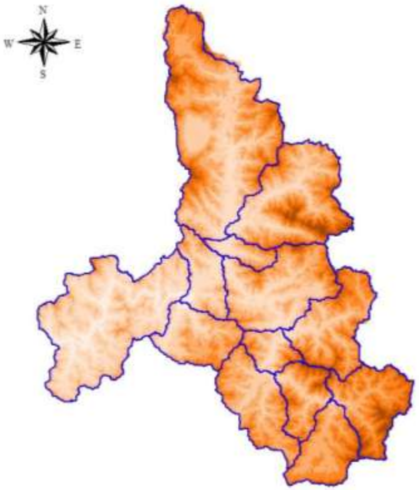
$$d_{rel} = 1 - \frac{\sum_{i=1}^{n}\left(\frac{O_i - S_i}{O_i}\right)^2}{\sum_{i=1}^{n}\left(\frac{\left|S_i - \bar{O}\right| + \left|O_i - \bar{O}\right|}{\bar{O}}\right)^2}$$

Modified SWAT auto-calibration can consider various efficiency criteria

❑ Methods

Modified SWAT Auto-calibration

- NSE with logarithmic values
- Index of agreement *d*
- Modified NSE and *d*
- Relative efficiency criteria NSE and *d*

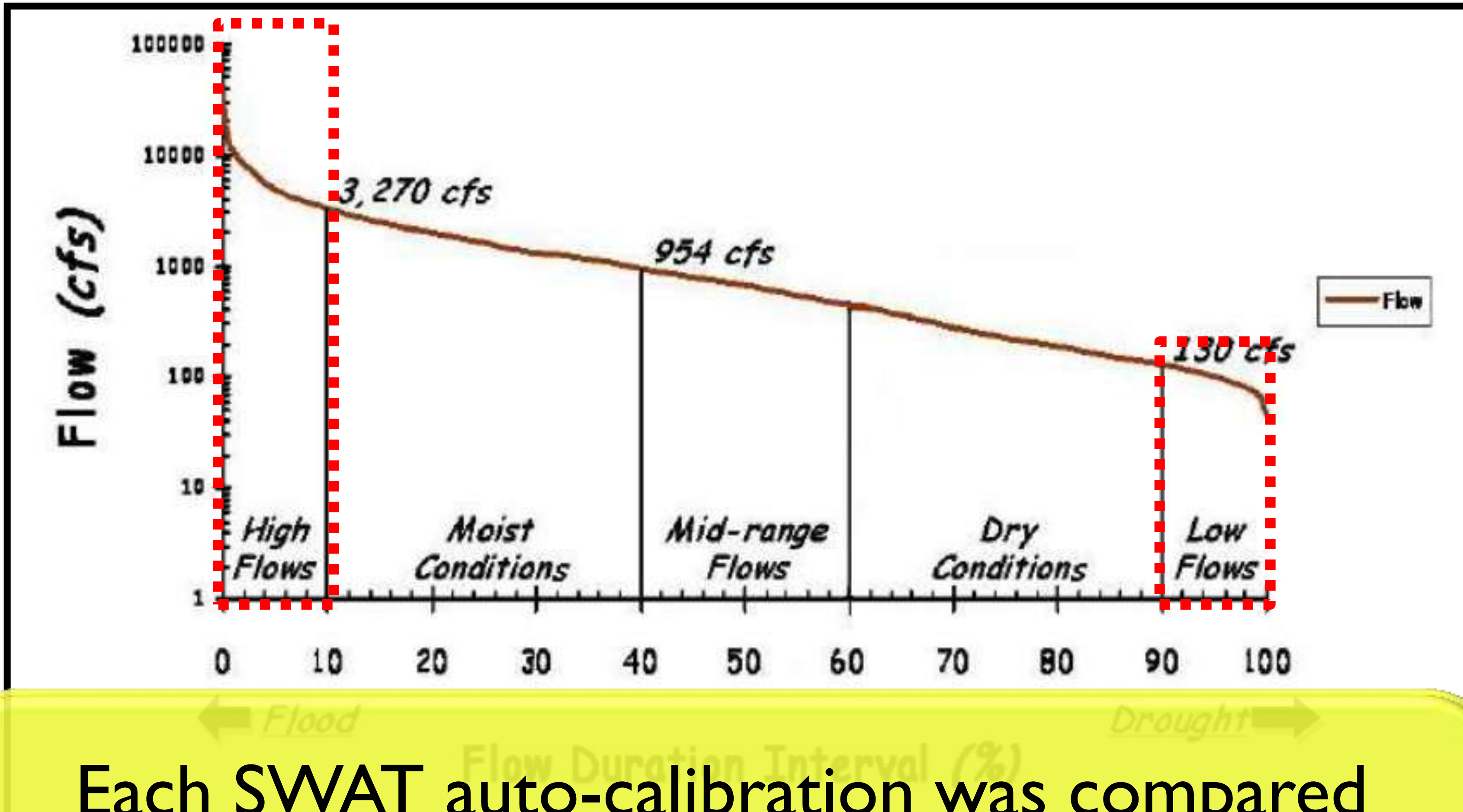


Daily Simulation in 2006

Methods

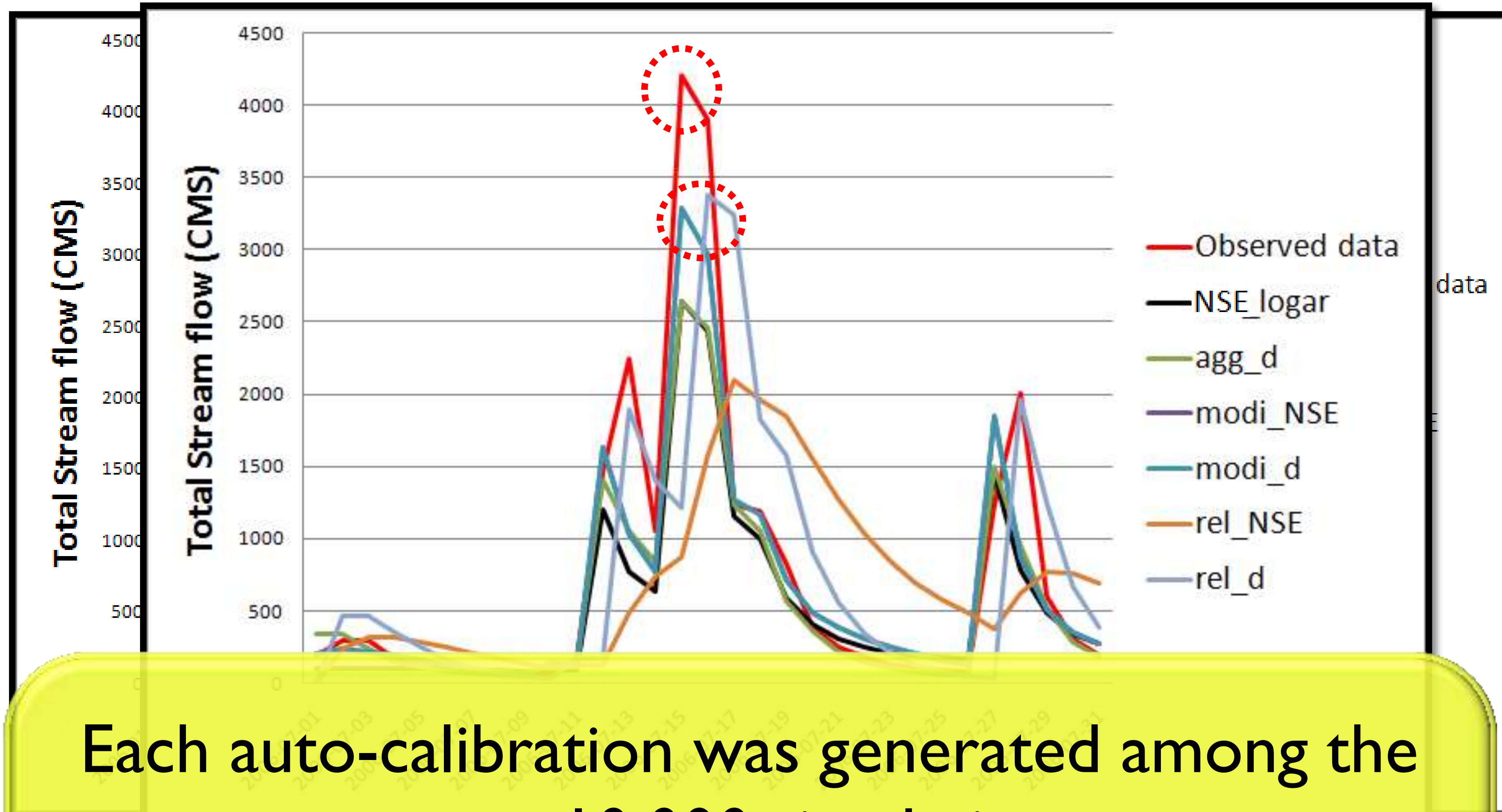
Parameter	Description
ALPHA_BF	**Baseflow alpha factor**
BIOMIX	**Biological mixing efficiency**
BLAI	**Maximum potential leaf area index**
CANMX	**Maximum canopy storage**
CH_K2	**Effective hydraulic conductivity in main channel alluvium**
CH_N2	**Mannings' "n" value for the main channel**
CN2	**SCS runoff curve number for moisture condition II**
EPCO	**Plant evaporation compensation factor**
ESCO	**Soil evaporation compensation factor**
GW_DELAY	**Groundwater delay**
GW_REVAP	**Groundwater "revap" coefficient**
GWQMN	**Threshold depth of water in the shallow aquifer required for return flow to occur**
REVAPMN	**Threshold depth of water in the shallow aquifer for "revap" to occur (mm)**
SFTMP	**Snow melt base temperature (° C)**
SLOPE	**Increase the lateral flow**
SLSUBBSN	**Average slope length**
SMFMN	**Minimum melt rate for snow (mm/° C/day)**
SMFMX	**Maximum melt rate for snow (mm/° C/day)**
SMTMP	**Snow melt base temperature (° C)**
SOL_AlB	**Moist soil albedo**
SOL_AWC	**Available water capacity of the soil layer**
SOL_K	**Saturated hydraulic conductivity (mm/hr)**
SOL_Z	**Soil depth (%)**
SURLAG	**Surface runoff lag time**
TIMP	**Snow pack temperature lag factor**
TLAPS	**Temperature laps rate (° C/km)**

❑ Methods



Each SWAT auto-calibration was compared in total stream flow, high and low flow conditions

❑ Results



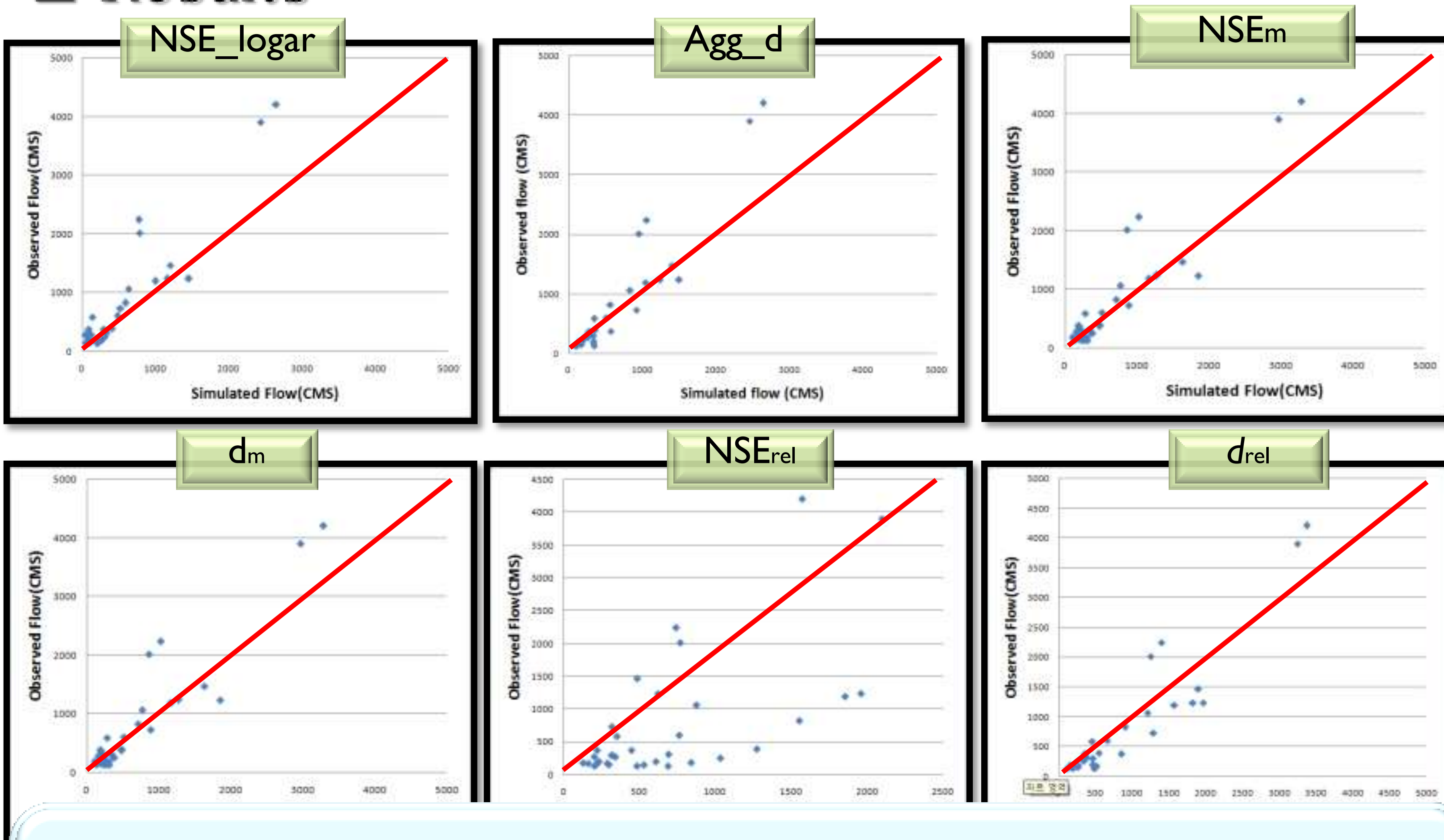
Each auto-calibration was generated among the over 10,000 simulations

❑ Results

Comparison of Auto-calibration for high flow condition(top 10%)

Efficiency criteria / Type of objective function	NSE	NSE_logar	Agg_d	NSE_m	d_m	NSE_{rel}	d_{rel}
NSE_logar	0.72	0.5	0.9	0.57	0.76	0.87	0.95
Agg_d	0.77	0.87	0.91	0.66	0.81	0.90	0.96
NSE_m	0.84	0.85	0.95	0.68	0.83	0.91	0.97
d_m	0.84	0.85	0.95	0.68	0.83	0.91	0.97
NSE_{rel}	0.40	0.37	0.71	0.28	0.56	-0.18	0.44
d_{rel}	0.86	0.79	0.96	0.63	0.80	0.68	0.90

Results



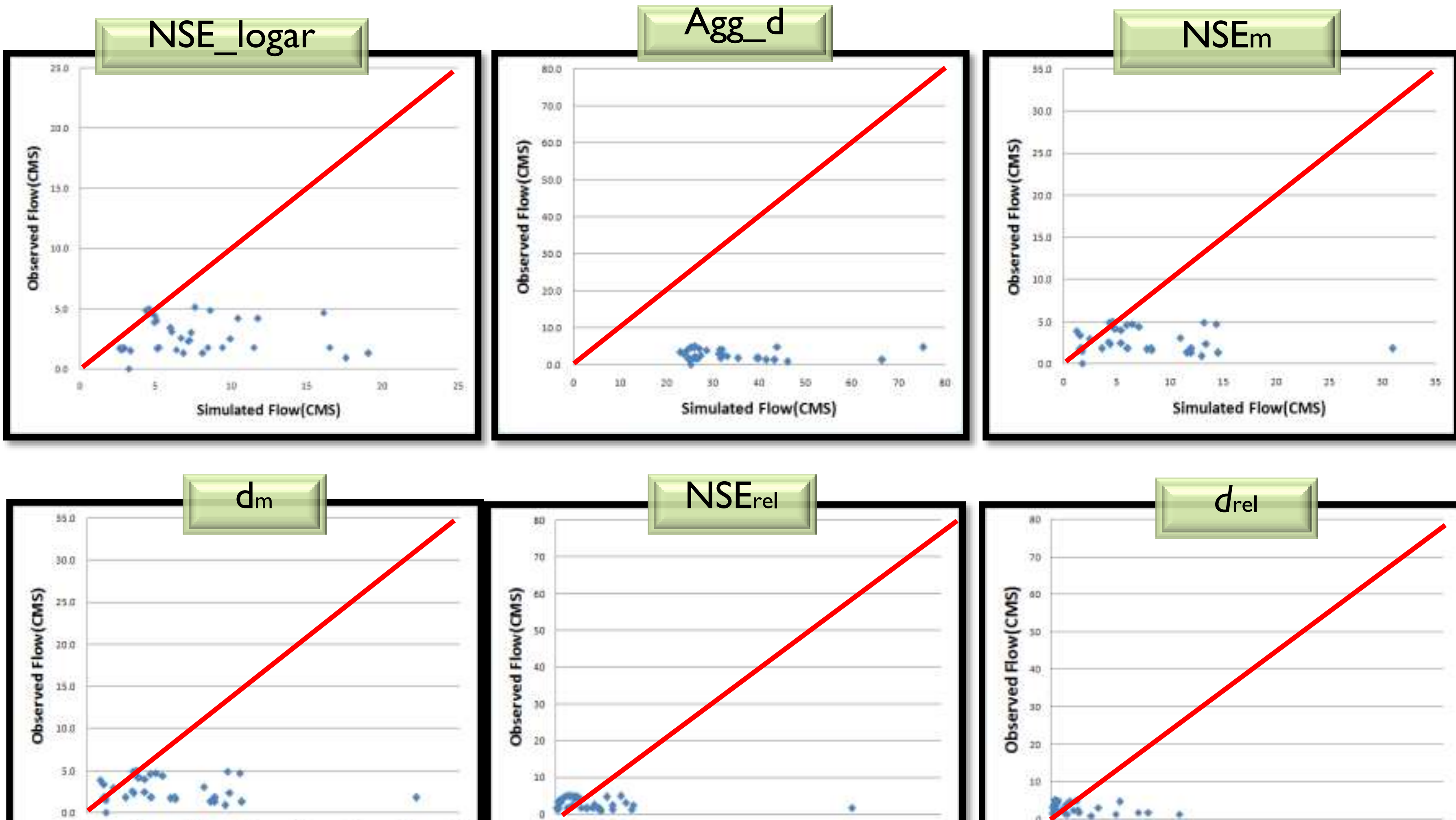
Reasonable result for high flow condition

Results

Comparison of Auto-calibration for low flow condition(bottom 10%)

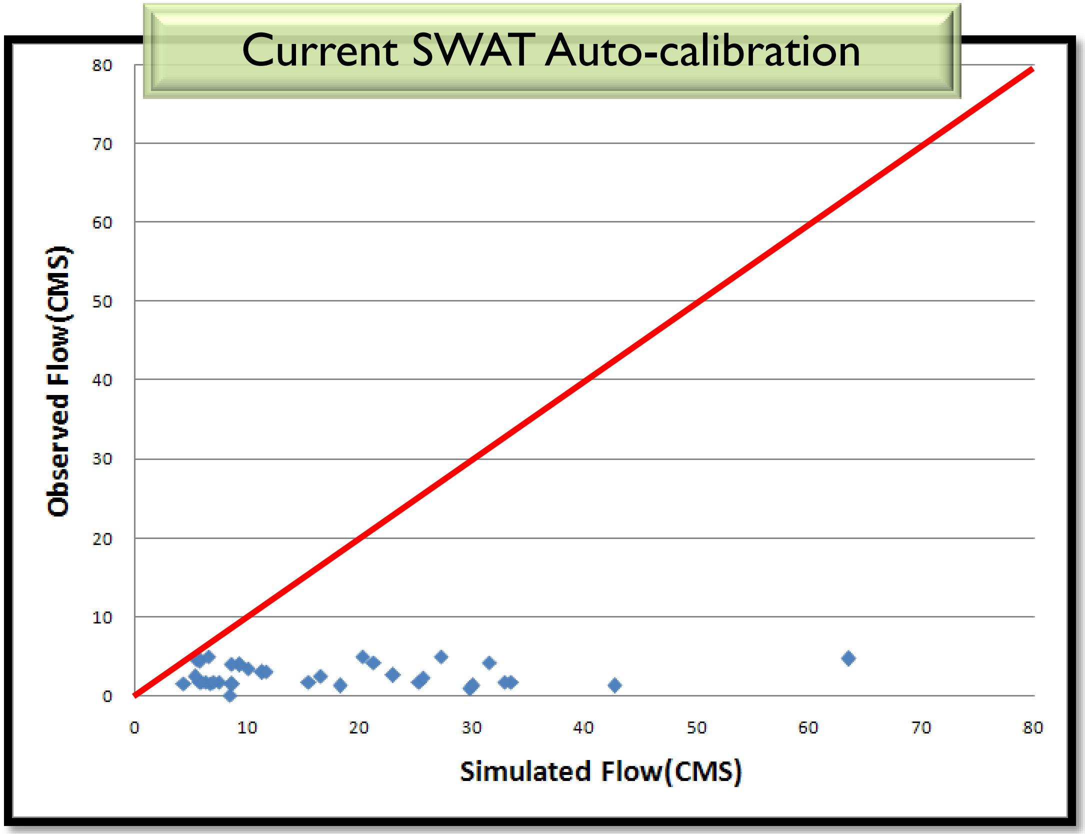
Efficiency criteria / Type of objective function	NSE	NSE_logar	Agg_d	NSEm	d_m	NSErel	d_{rel}
NSE_logar	**-20.59**	**-0.20**	**0.35**	**-2.80**	**0.20**	**-88.08**	**-2.14**
Agg_d	**-535.70**	**-1.09**	**0.07**	**-23.36**	**0.04**	**-1426.74**	**-1.29**
NSEm	**-29.49**	**-0.15**	**0.16**	**-3.00**	**0.22**	**-95.33**	**-1.46**
d_m	**-29.49**	**-0.15**	**0.16**	**-3.00**	**0.22**	**-95.33**	**-1.46**
NSErel	**-70.55**	**-7.16**	**0.11**	**-3.72**	**0.16**	**-2254.60**	**-1.38**
d_{rel}	**-24.02**	**-6.70**	**0.24**	**-2.32**	**0.20**	**-1056.67**	**-2.00**

❑ Results



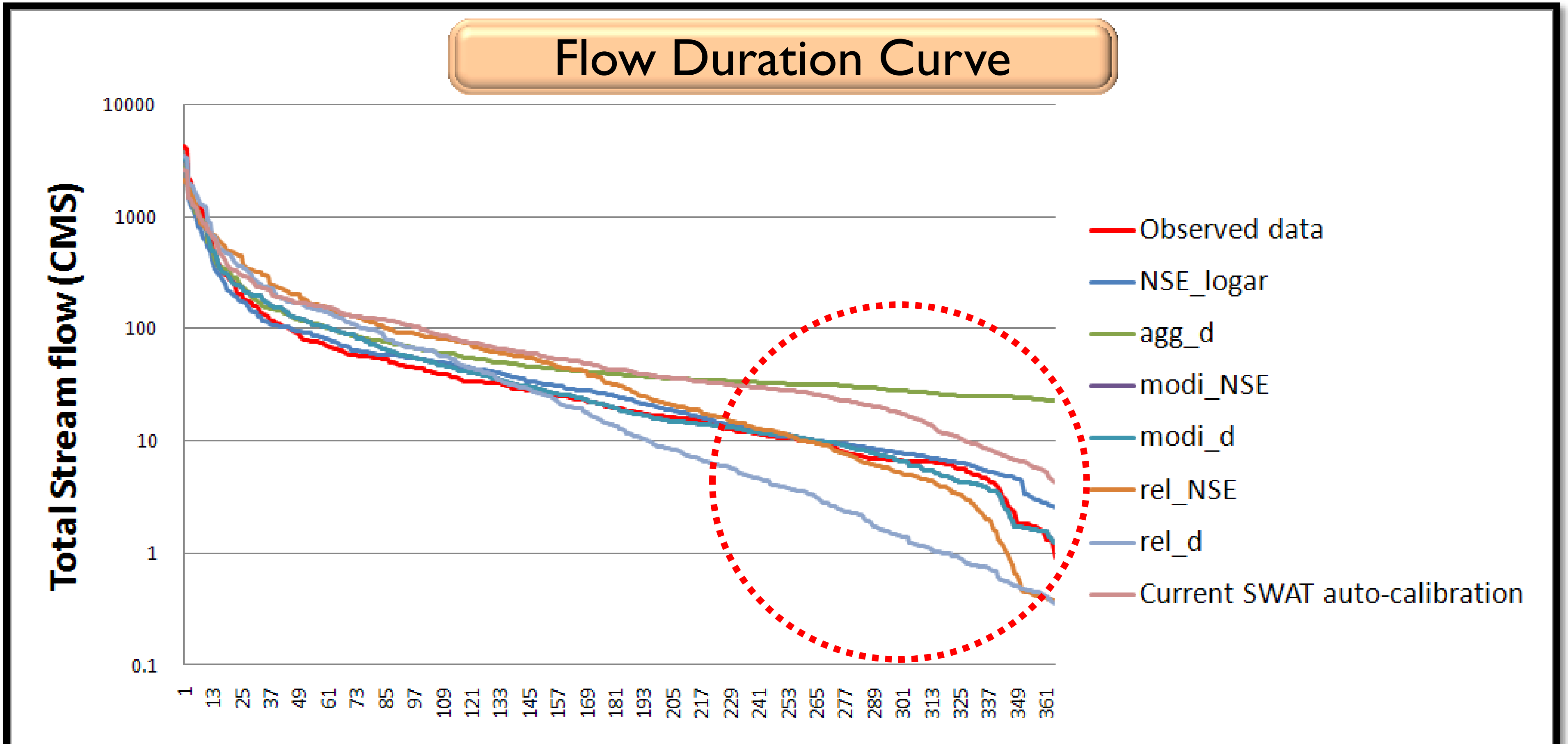
Unreasonable calibration result for low flow condition

❑ Results



Unreasonable calibration result for low flow condition

❑ Results



Flow Duration Curve
Total Stream flow (CMS)
10000
1000
100
10
1
0.1
1
13
25
37
49
61
73
85
97
109
121
133
145
157
169
181
193
205
217
229
241
253
265
277
289
301
313
325
337
349
361
Observed data
NSE_logar
agg_d
modi_NSE
modi_d
rel_NSE
rel_d
Current SWAT auto-calibration

❑ Conclusion

- In this study, SWAT Auto-calibration was modified by different efficiency criteria.

- As a result of this study, Auto-calibrations modified by modi_NSE, modi_d and rel_d show the better calibration result for high flow conditions.

❑ Conclusion

- In low flow conditions, the results of all auto-calibrations are unacceptable.

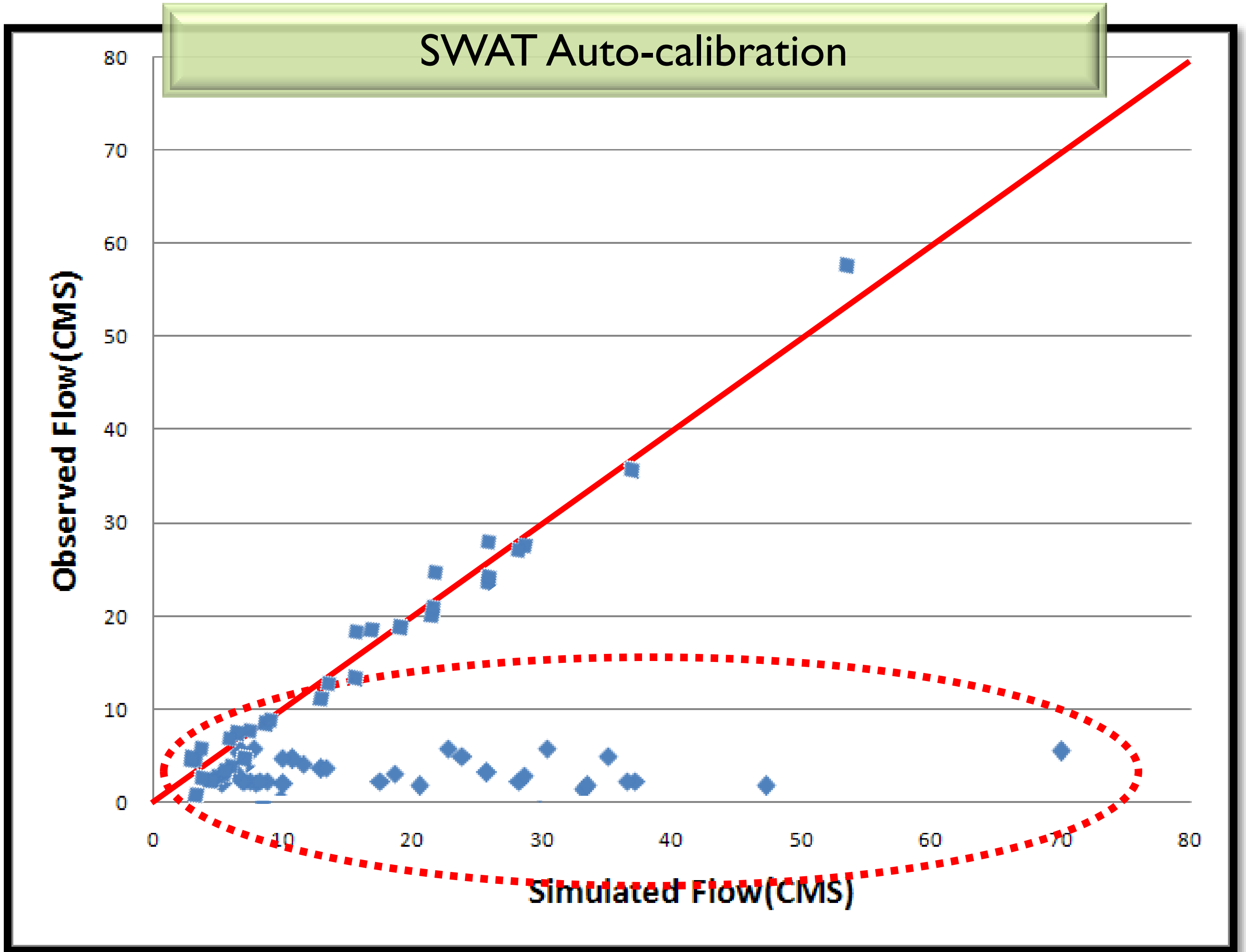
- SWAT Auto-calibration should be improved and modified to make the better simulation for low flow conditions.

❑ Conclusion

- For better calibration and validation of hydrological modeling, combination and comparison of different efficiency criteria is needed.

- The result of this study can be used to improve the accuracy of SWAT Auto-calibration for various flow coditions.

❑Future study



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Thank you for your attention,

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