SWAT Soil & Water Assessment Tool
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Comparing Single-Site and Multi-Site Calibration of SWAT+ in a Moroccan Semi-Arid watershed

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PhD Hydrology

Summary

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- Swat+ Toolbox capabilities
- Watershed description
- Input data
- Model verification
- Soft calibration
- Set Calibration/Validation periods
- Sensitivity analysis
- Single-site calibration
- Multisite one step calibration
- Multisite multistep calibration
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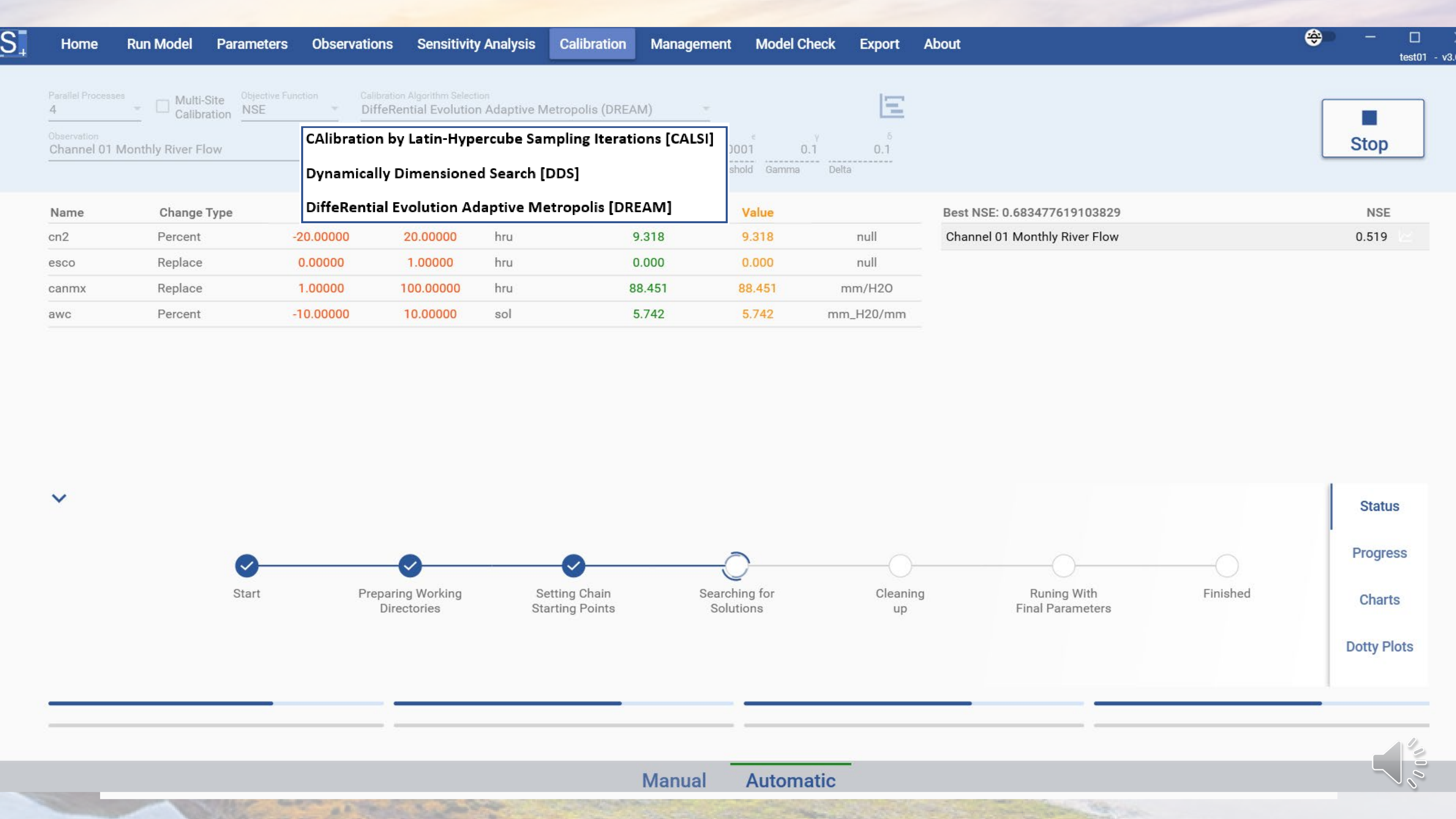
Introduction

- The calibration phase is a crucial step in any hydrological modeling process;
- In engineering, the main challenge lies in data collection, processing, and establishing the rainfall-runoff relationship;
- When multiple hydrological stations are present, calibration is performed basin by basin, without the possibility of processing the entire network simultaneously;
- This is where a tool like the SWAT+ Toolbox becomes essential, as it enables processing of the entire hydrometric network and improves the regionalization of the calibration process
- Here we have a sophisticated tool. The current question is how to leverage this tool to Improve the calibration model at the outlet level of a watershed ?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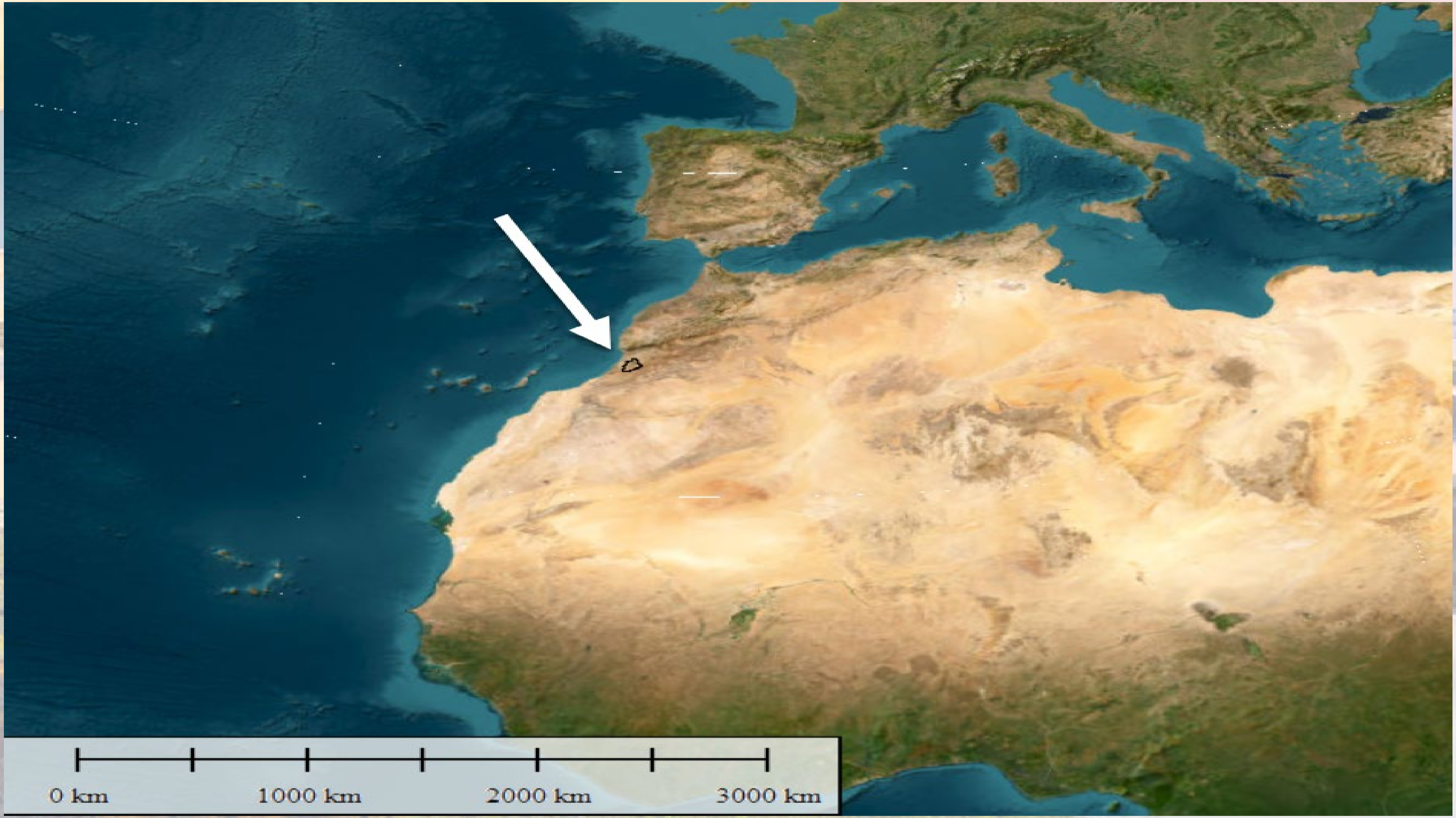
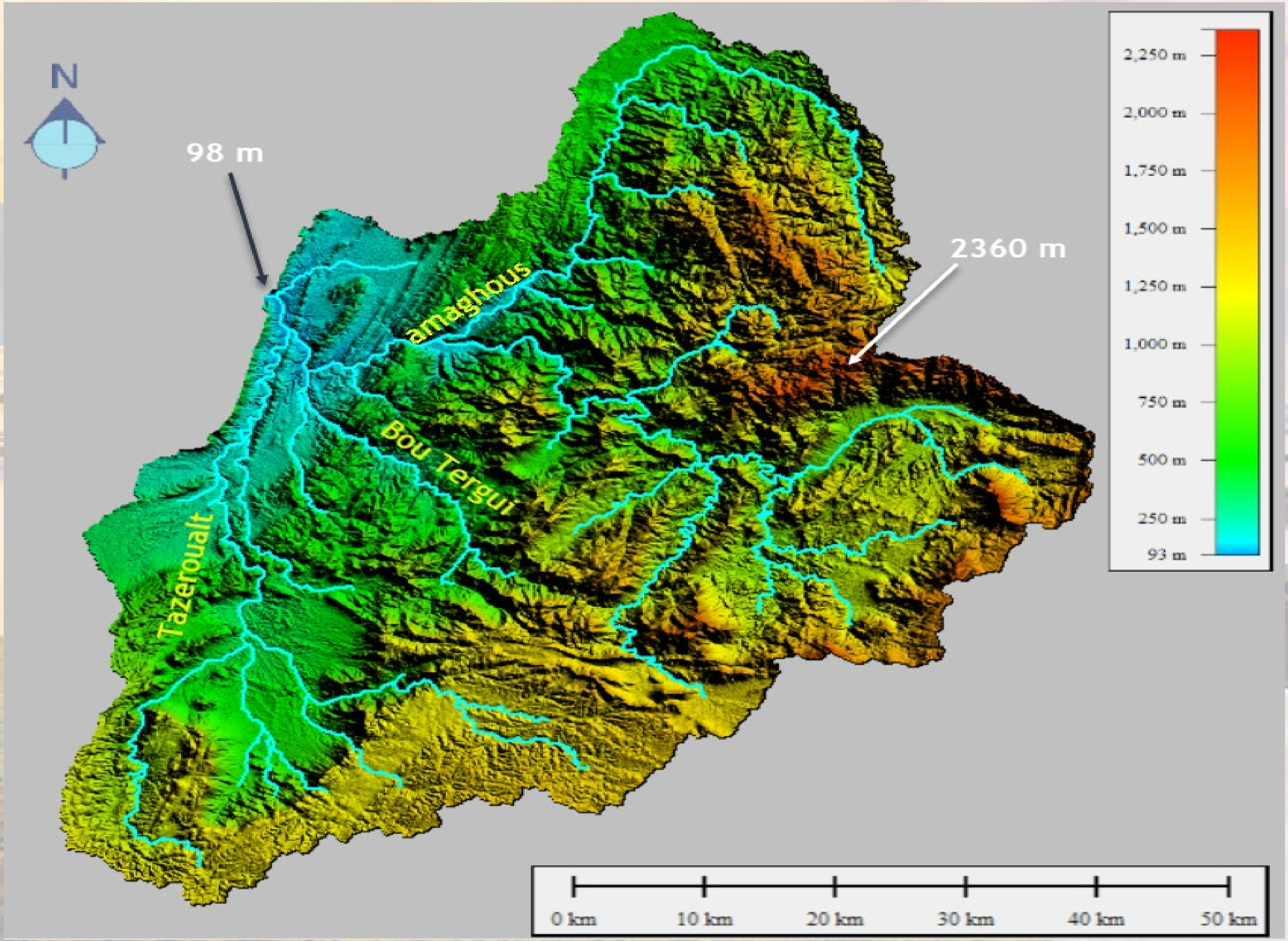
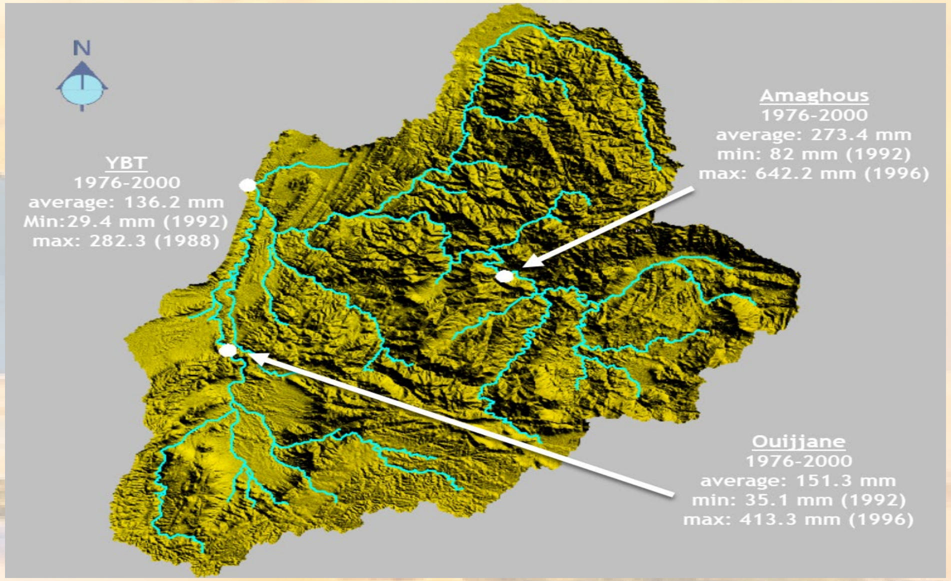
Multi-Site Calibration
Objective Function
NSE
Calibration Algorithm Selection
DiffeRential Evolution Adaptive Metropolis (DREAM)
Observation
Channel 01 Monthly River Flow
CAlibration by Latin-Hypercube Sampling Iterations [CALSI]
Dynamically Dimensioned Search [DDS]
DiffeRential Evolution Adaptive Metropolis [DREAM]
Gamma
Delta
Stop
Name | Change Type | Value
cn2 | Percent | -20.00000 | 20.00000 | hru | 9.318 | 9.318 | null
esco | Replace | 0.00000 | 1.00000 | hru | 0.000 | 0.000 | null
canmx | Replace | 1.00000 | 100.00000 | hru | 88.451 | 88.451 | mm/H2O
awc | Percent | -10.00000 | 10.00000 | sol | 5.742 | 5.742 | mm_H20/mm
Best NSE: 0.683477619103829
NSE
Channel 01 Monthly River Flow 0.519
Start
Preparing Working Directories
Setting Chain Starting Points
Searching for Solutions
Cleaning up
Runing With Final Parameters
Finished
Status
Progress
Charts
Dotty Plots
Manual
Automatic

Watershed description

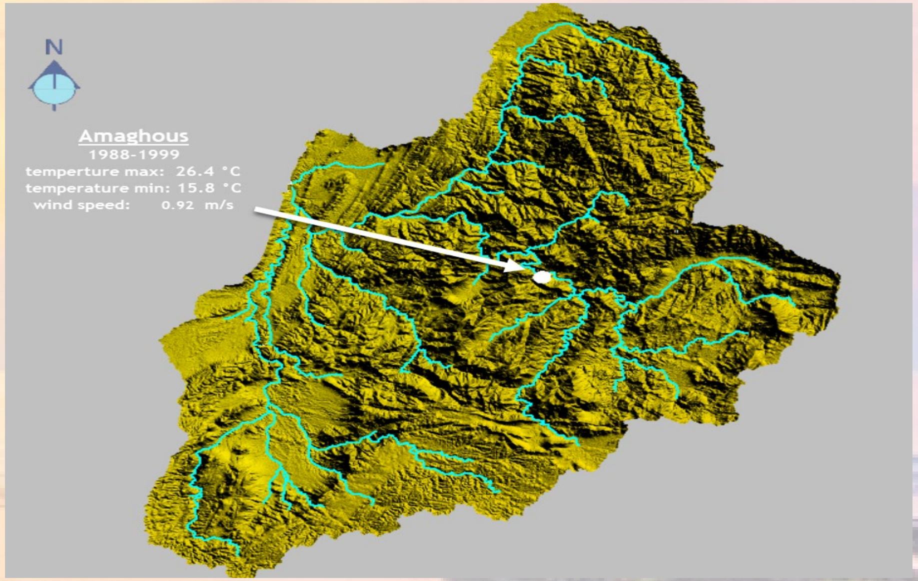



N
98 m
2360 m
amaghous
Bou Tergui
Tazeroualt
2,250 m
2,000 m
1,750 m
1,500 m
1,250 m
1,000 m
750 m
500 m
250 m
93 m
0 km
10 km
20 km
30 km
40 km
50 km

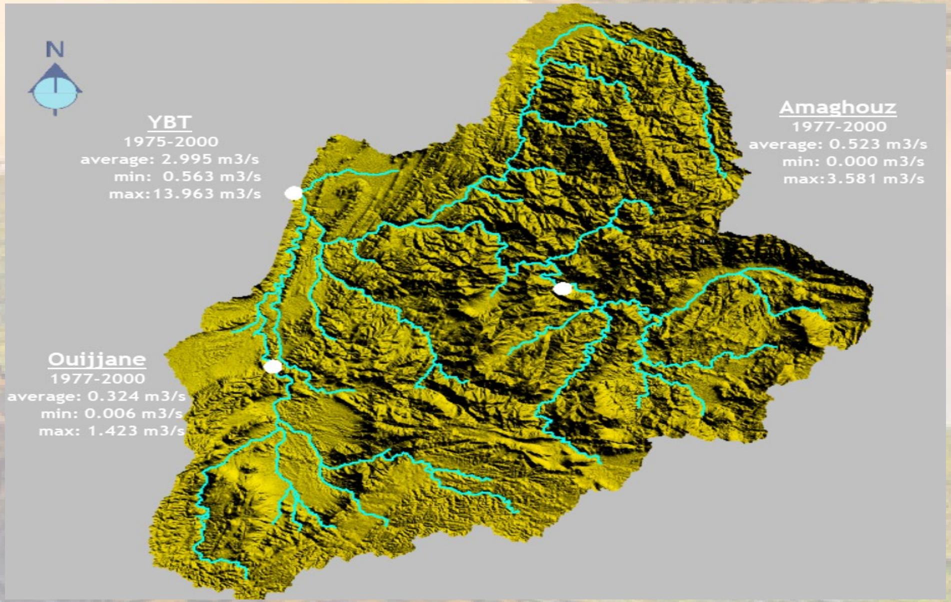
Input data



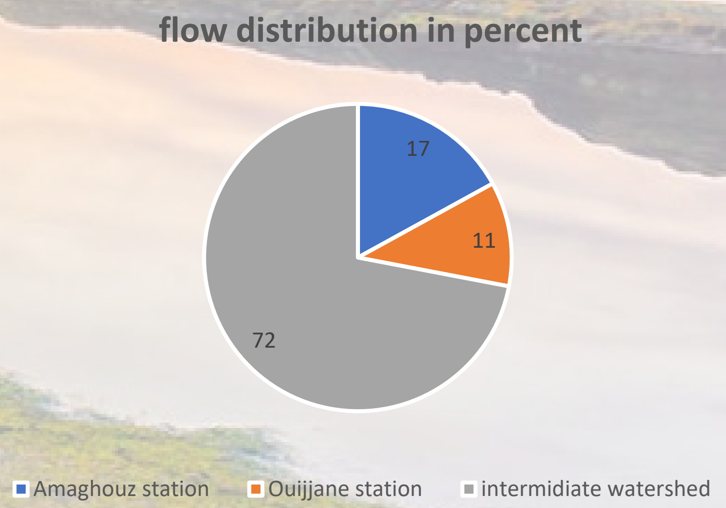
N
YBT
1976-2000
average: 136.2 mm
Min:29.4 mm (1992)
max: 282.3 (1988)
Amaghous
1976-2000
average: 273.4 mm
min: 82 mm (1992)
max: 642.2 mm (1996)
Ouijjane
1976-2000
average: 151.3 mm
min: 35.1 mm (1992)
max: 413.3 mm (1996)



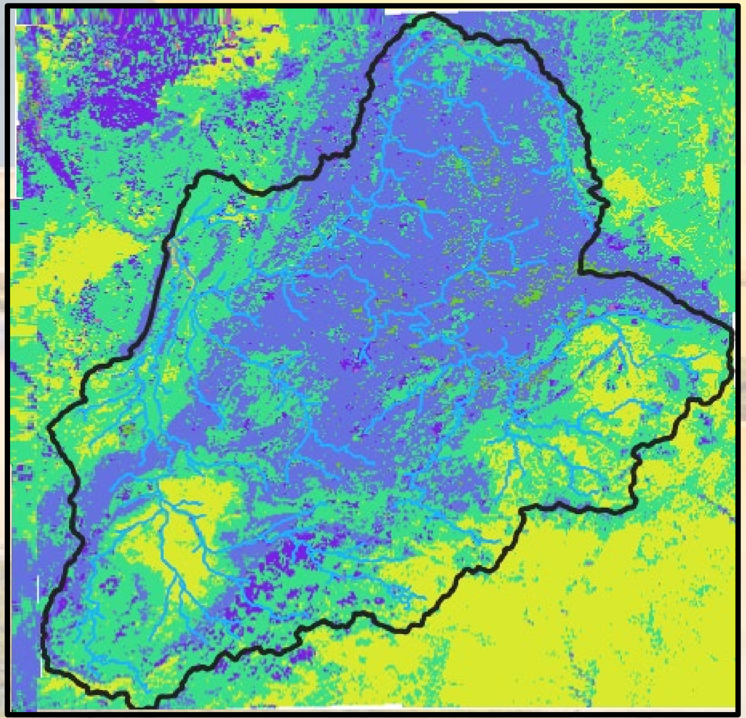
N
Amaghous
1988-1999
temperture max: 26.4 °C
temperature min: 15.8 °C
wind speed: 0.92 m/s



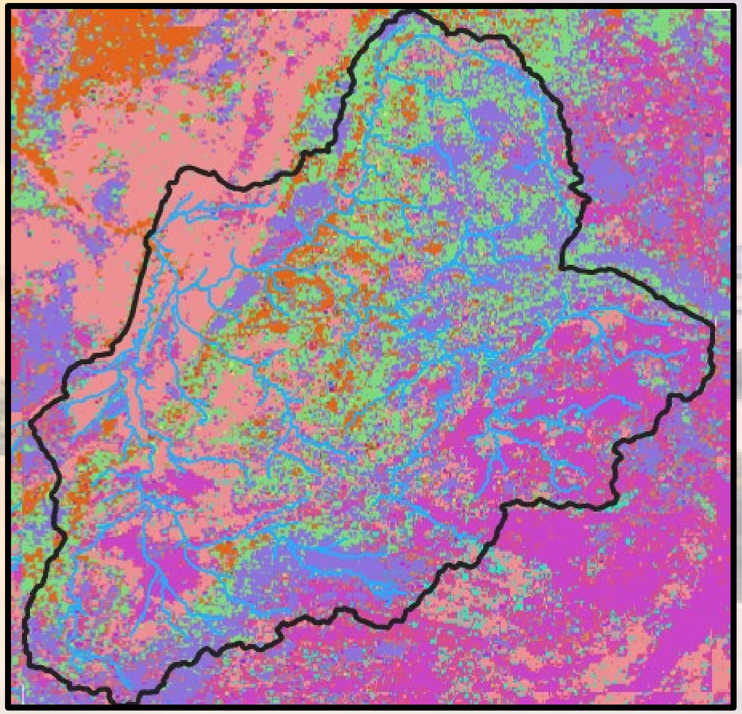
N
YBT
1975-2000
average: 2.995 m3/s
min: 0.563 m3/s
max:13.963 m3/s
Amaghouz
1977-2000
average: 0.523 m3/s
min: 0.000 m3/s
max:3.581 m3/s
Ouijjane
1977-2000
average: 0.324 m3/s
min: 0.006 m3/s
max: 1.423 m3/s



flow distribution in percent
17
11
72
Amaghouz station
Ouijjane station
intermidiate watershed



Copernicus global land cover **(100 m)**

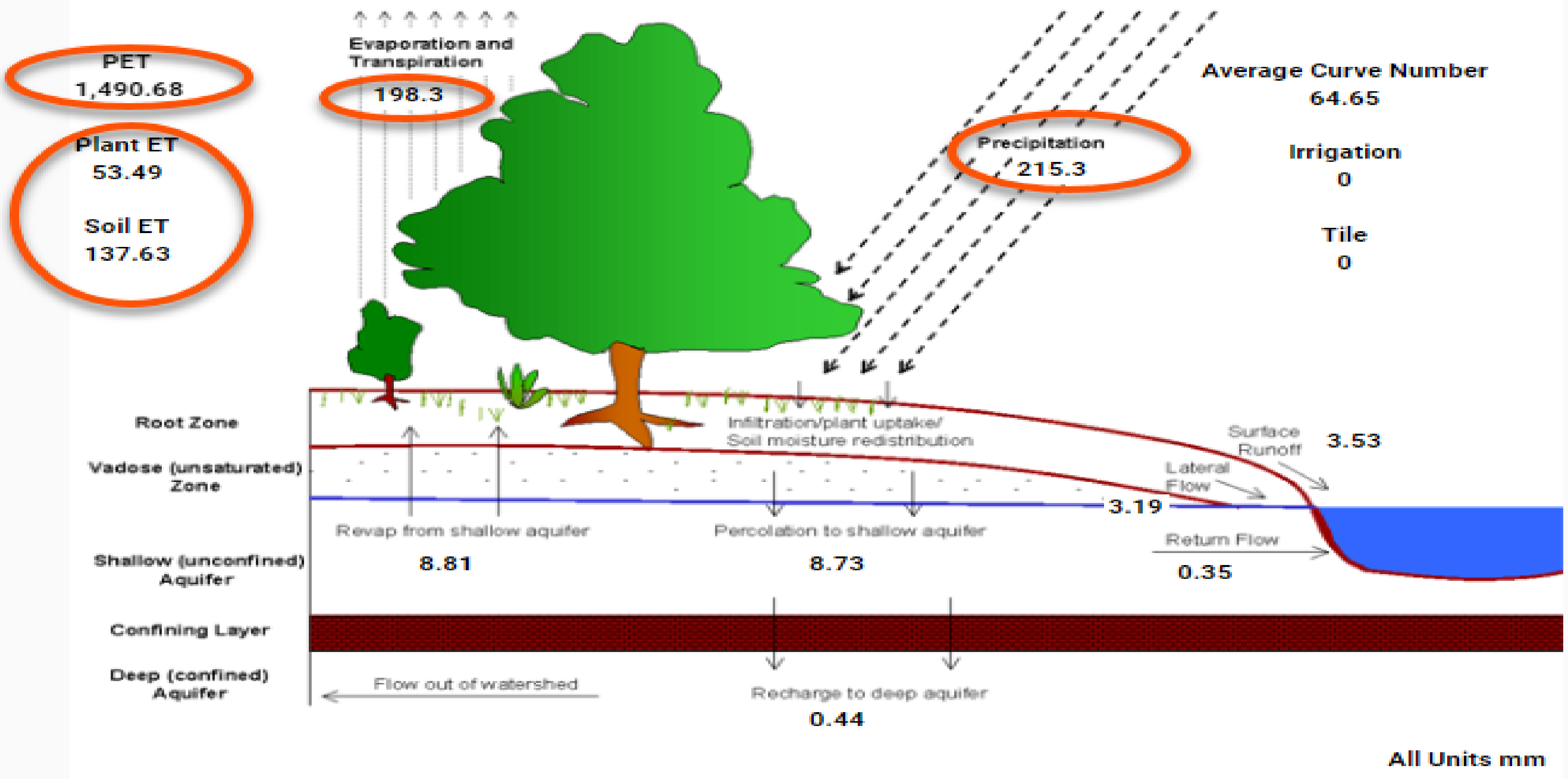


DSOL map: Digital Soil Open Land map **(250 m)**

Model verification

Parameter	Measured values in the watershed
PT	180 mm
PET	1410 mm

Amaghous	Ouijjane	YBT
273.4 mm	151.3	136.2



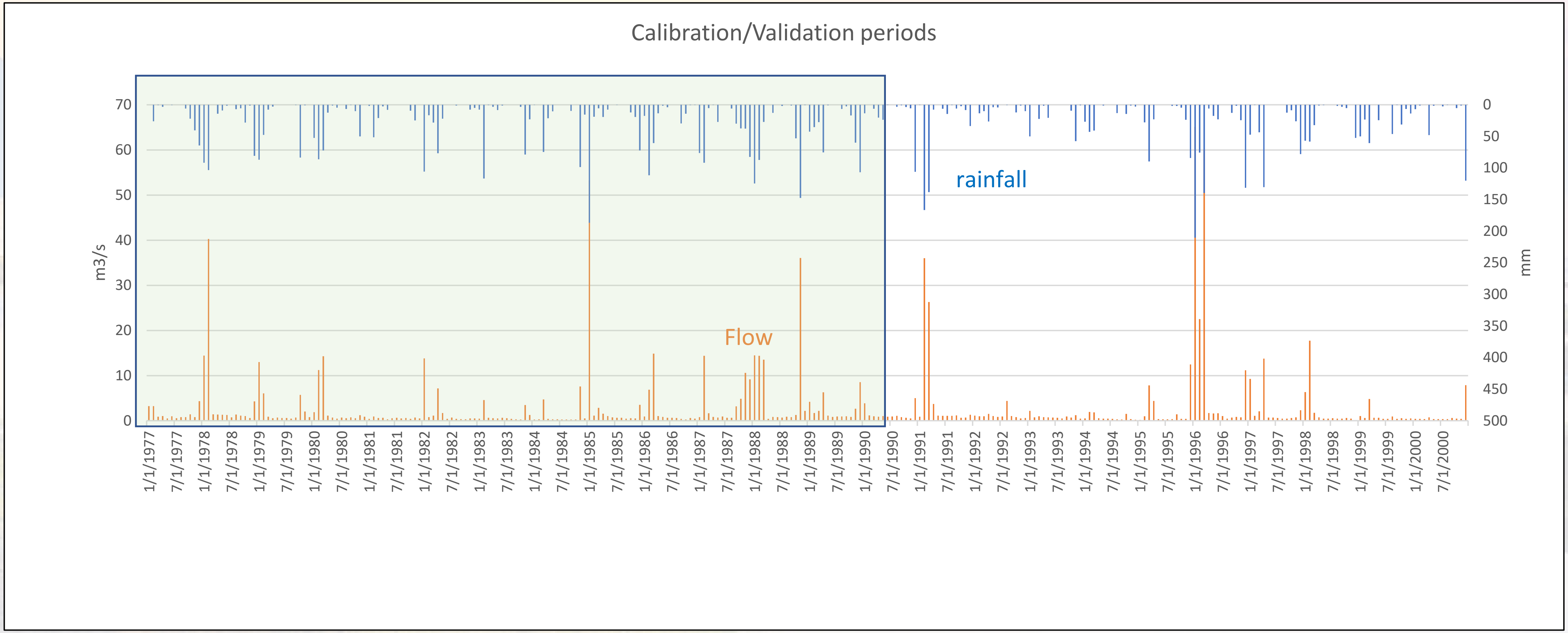
Soft calibration

$$\text{Water yield ratio} = \frac{\text{total water yield}}{\text{precipitation}} = \mathbf{0.119}$$

$$\text{BFI} = \frac{\text{base flow}}{\text{total flow}} = \mathbf{0.0437}$$

BFI: base flow index

Calibration/Validation periods



Sensitivity Analysis

test01

Sensitivity Analysis Method: Sobol

Use Observations: No / Yes

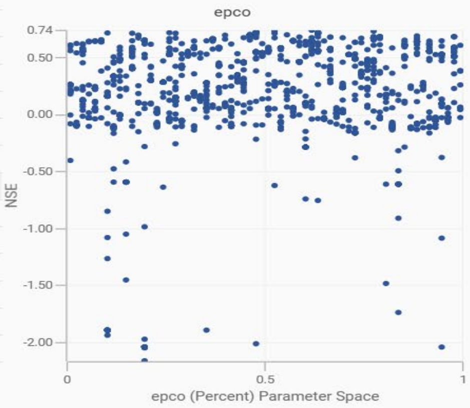
Observation: Channel 1 Monthly River Flow

Seed: 50 (1600 Samples)

Parallel Processes: 3

▶ Analyse

1st Order Sensitivity	Name	Group	Change Type	
0.2620420056	esco	hru	Replace	null
0.1685973833	cn2	hru	Percent	null
0.1595372117	canmx	hru	Replace	mm/H2O
0.0165098200	awc	sol	Percent	mm_H20/mm
0.0032599903	revap_min	aqu	Replace	m
0.0017778589	k	sol	Percent	mm/hr
0.0006172111	alpha	aqu	Replace	days
0.0000046663	lat_ttime	hru	Percent	days
0.0000000000	epco	hru	Percent	null
0.0000000000	bf_max	aqu	Replace	mm/H2O
0.0000000000	chk	rte	Percent	mm/hr
-0.0006824624	revap_co	aqu	Replace	null
-0.0025869343	flo_min	aqu	Percent	m
-0.0040548773	perco	hru	Replace	fraction
-0.0067552651	cn3_swf	hru	Replace	null



Export as Image

Status : Finished Analysis

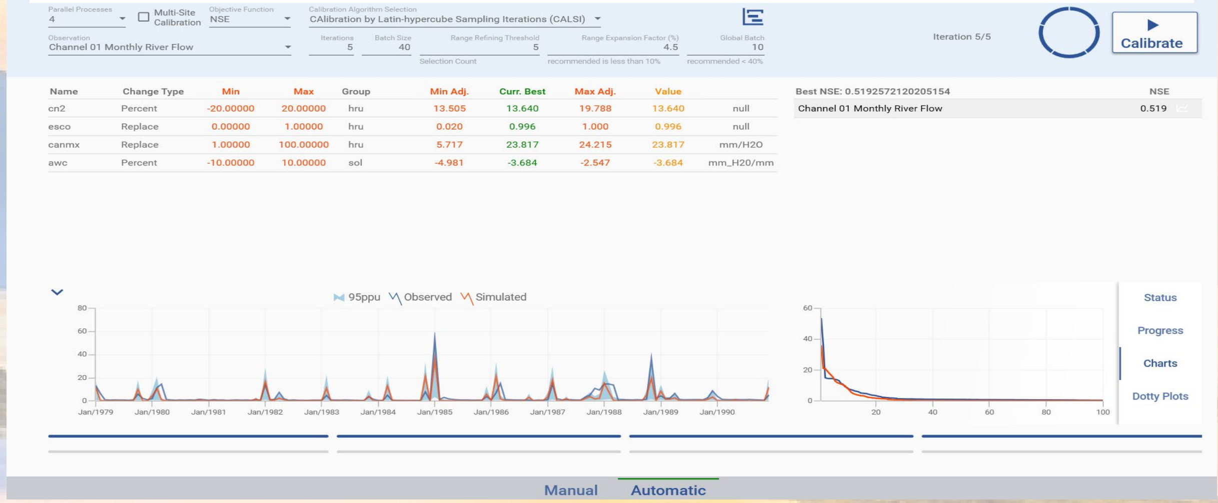
Progress : 100.00 %

Start → Generating Parameter Samples → Preparing Working Directories → Running Parameter Samples → Agregating Results → Analysing Sensitivity → Finished

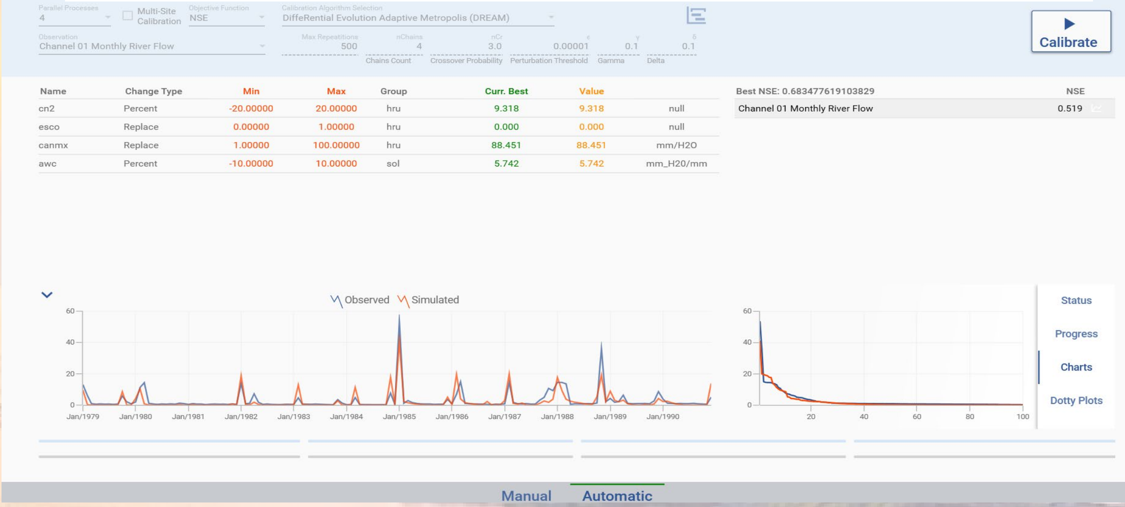
ESCO	Soil evaporation compensation factor
CN2	initial's runoff SCS curve number for moisture condition II
CANMX	Maximum canopy storage (mm H2O)
SOL_AWC	available water capacity of the soil layer (mm H2O/mm soil)

Single site calibration

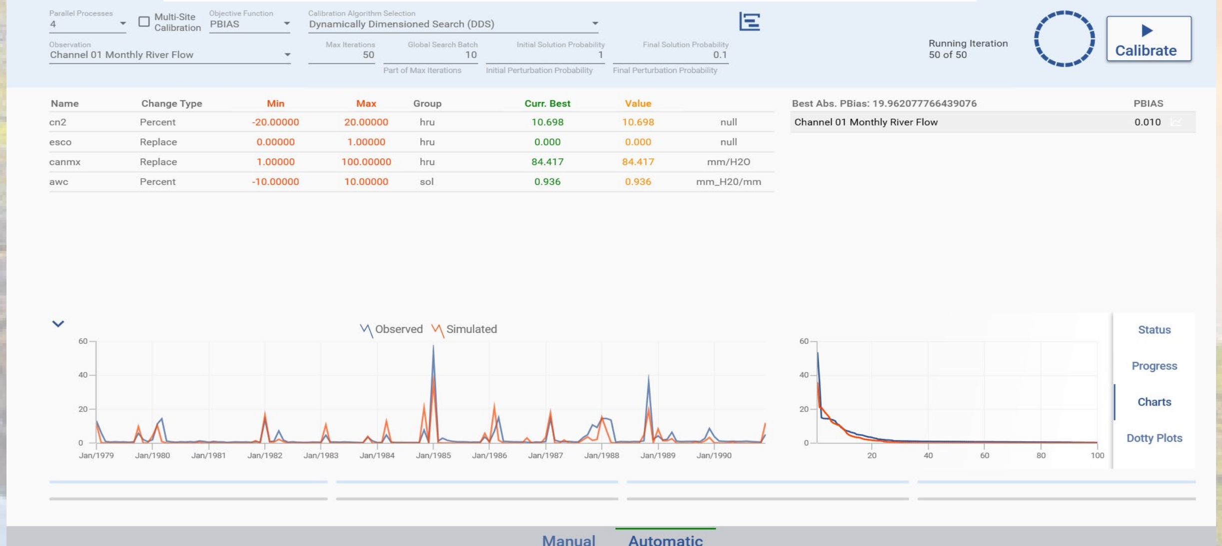
CALSI: CAlibration by Latin-hypercube Sampling Iterations



DREAM: DiffeRential Evolution Adaptive Metropolis

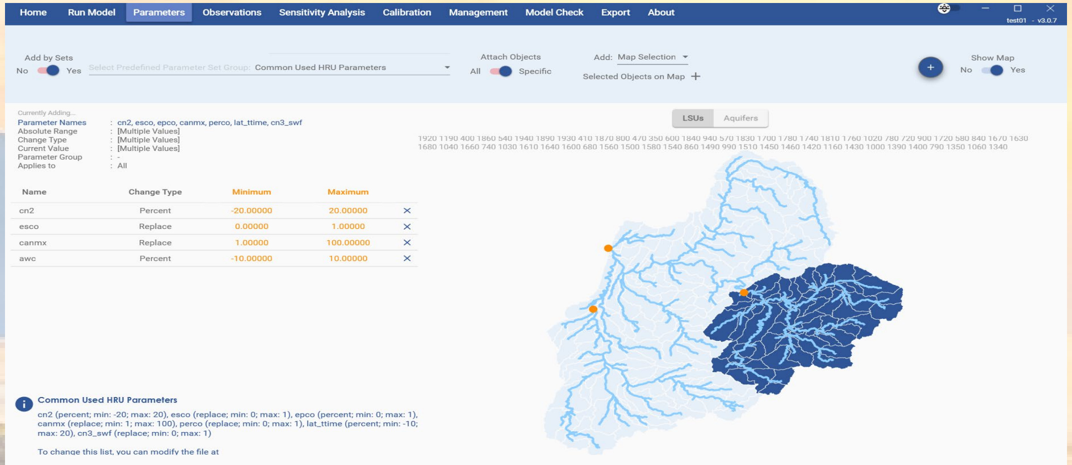


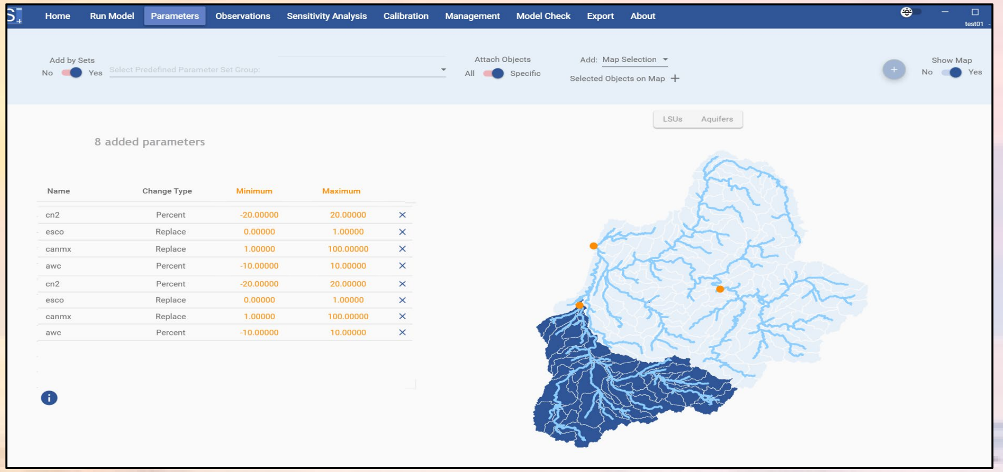
DDS: Dynamically Dimensioned Search

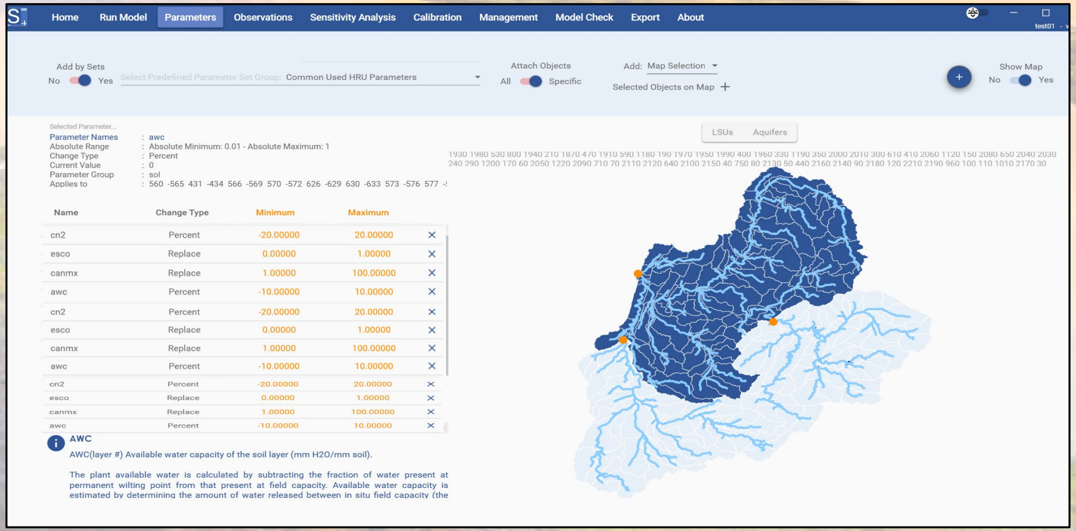


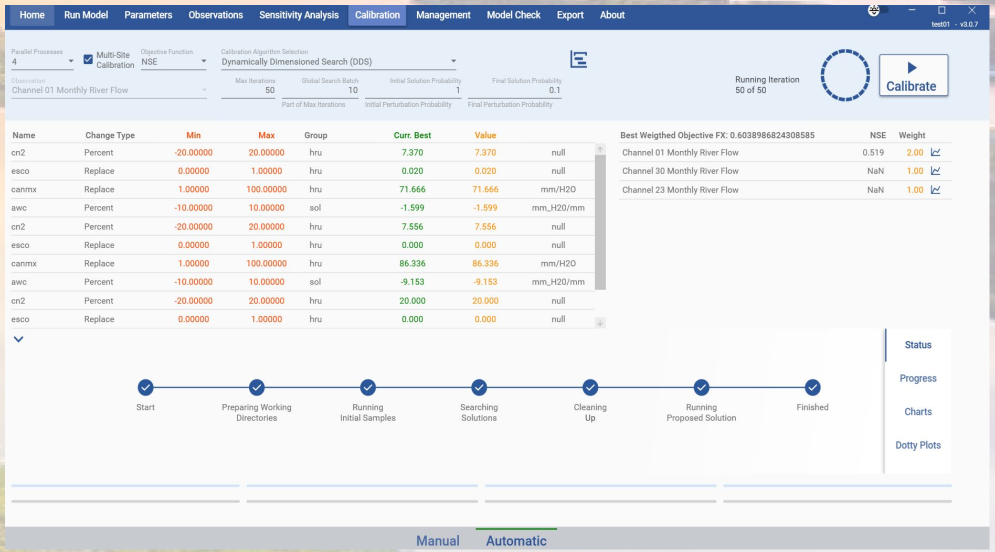
method	NSE
CALSI	0.614
DREAM	0.669
DDS	0.686

Multisite-one step- calibration

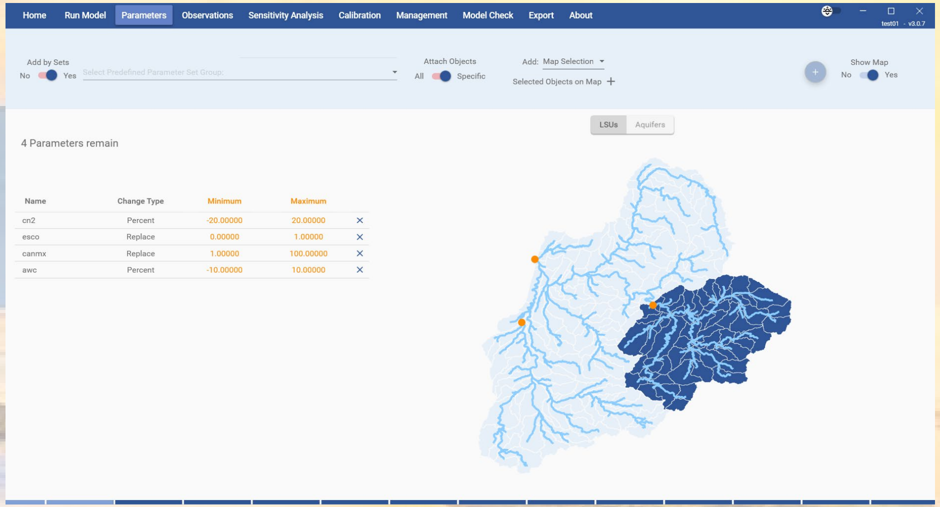


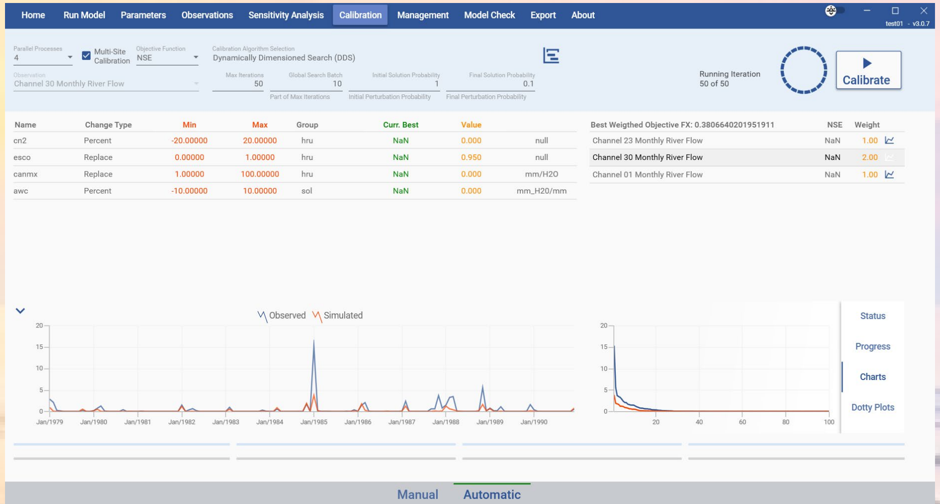


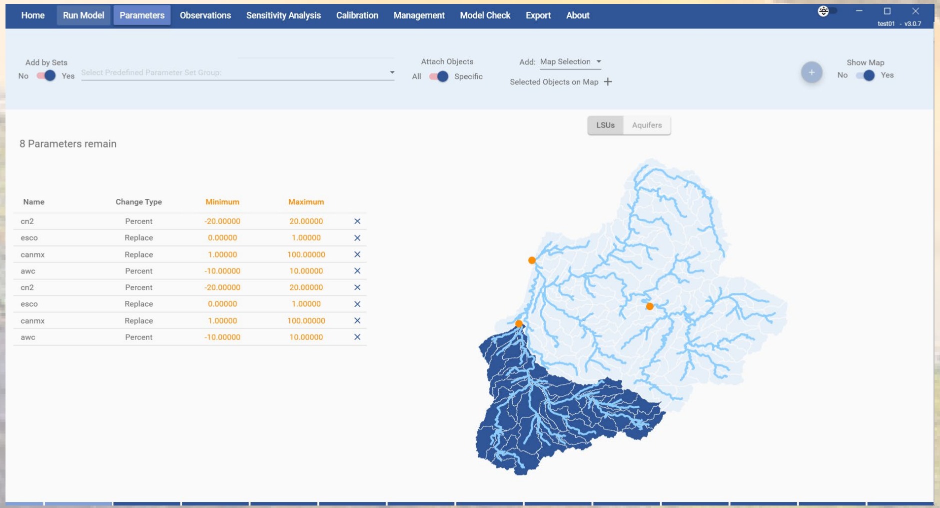


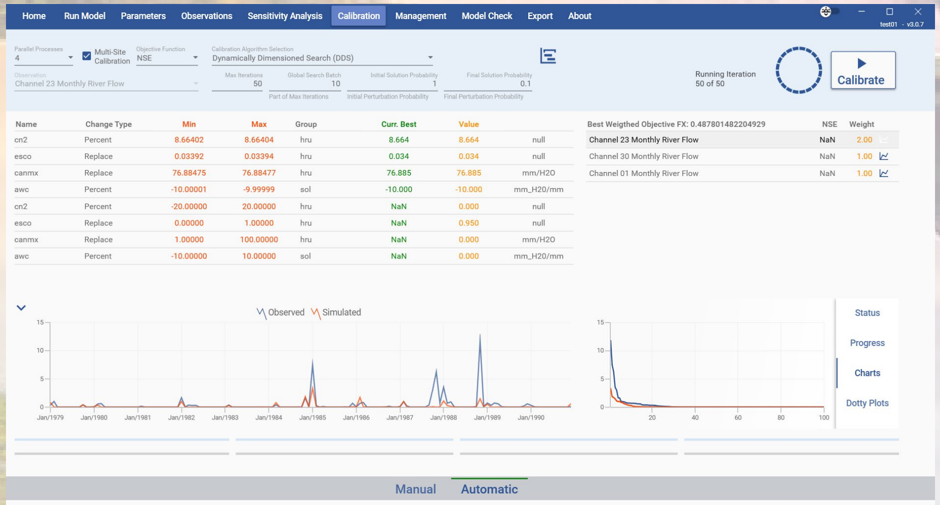


Multisite-Multistep- calibration

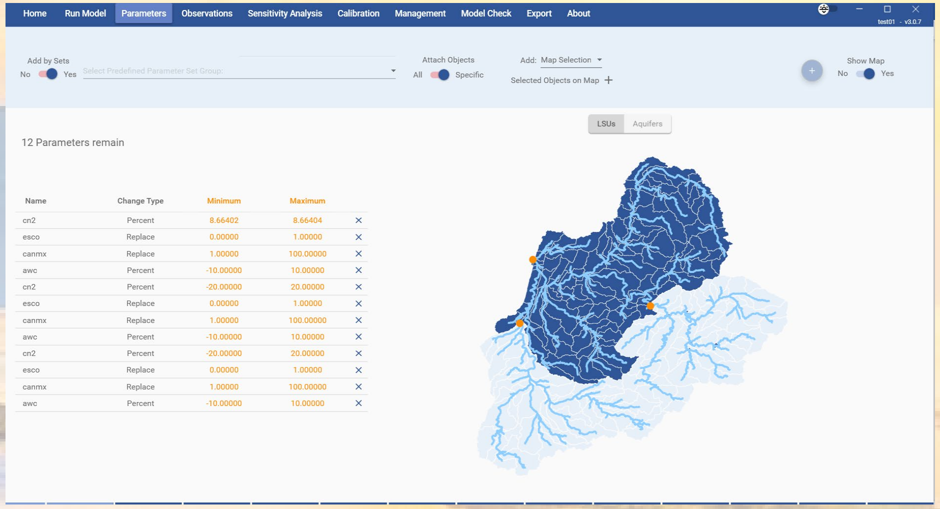


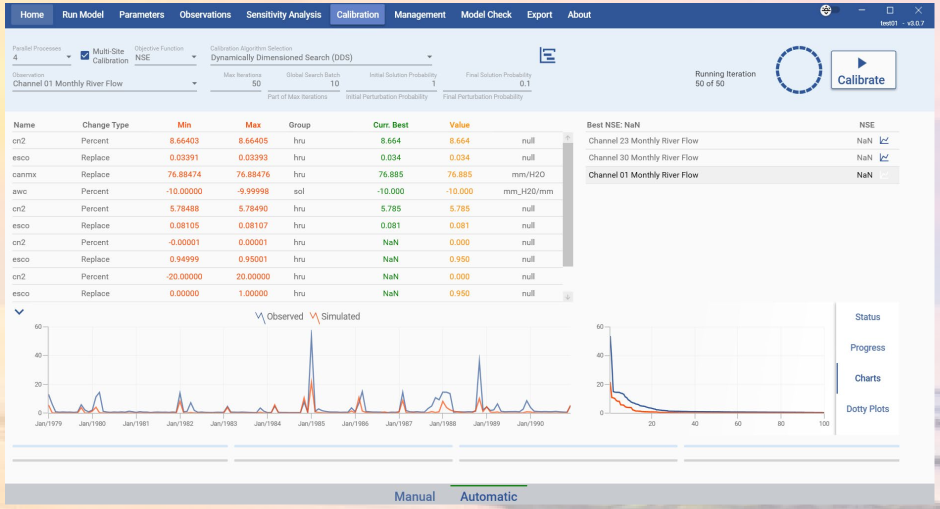






Multisite-Multistep- calibration





Results analysis

	Amaghouz		Ouijjane		YBT	
calibration	NSE	PBIAS	NSE	PBIAS	NSE	PBIAS
single-site	0.66	-6.93	0.41	8.77	0.52	36.07
multisite-one-step	0.65	2.80	0.39	21.21	0.69	18.15
multisite-multi-step	0.66	-2.02	0.40	15.80	0.69	2.16

	Amaghouz		Ouijjane		YBT	
validation	NSE	PBIAS	NSE	PBIAS	NSE	PBIAS
single-site	0.49	23.17	-0.06	-34.74	0.52	36.07
multisite-one-step	0.47	26.96	-0.10	-13.53	0.53	33.83
multisite-multi-step	0.50	17.49	0.01	-16.72	0.55	23.71

Regarding calibration, we observe a clear improvement in the Nash-Sutcliffe Efficiency (NSE) when shifting from single-site to multi-site calibration at the YBT station. For validation, a slight improvement is noted at the YBT station, which is not the case for the Amaghouz and Ouijjane stations. This limited improvement at YBT station can be explained by: (1) the low flow contribution of Amaghouz and Ouijjane stations to the total watershed discharge (28%), and (2) the poor model performance at Ouijjane station.

Conclusion

- The results indicate that SWAT+Toolbox significantly enhances hydrological model performance at the outlet of a multi-station watershed systems;

- Calibration efficiency showed substantial gains (ΔNSE = +0.17), while validation exhibited incremental improvements (ΔNSE = +0.03);

- These outcomes are contingent upon: (i) the relative discharge contributions of secondary stations, and (ii) the calibration accuracy achieved at intermediate monitoring points.