On the use of satellite soil moisture data in spatio-temporal model calibration for a Mediterranean catchment.

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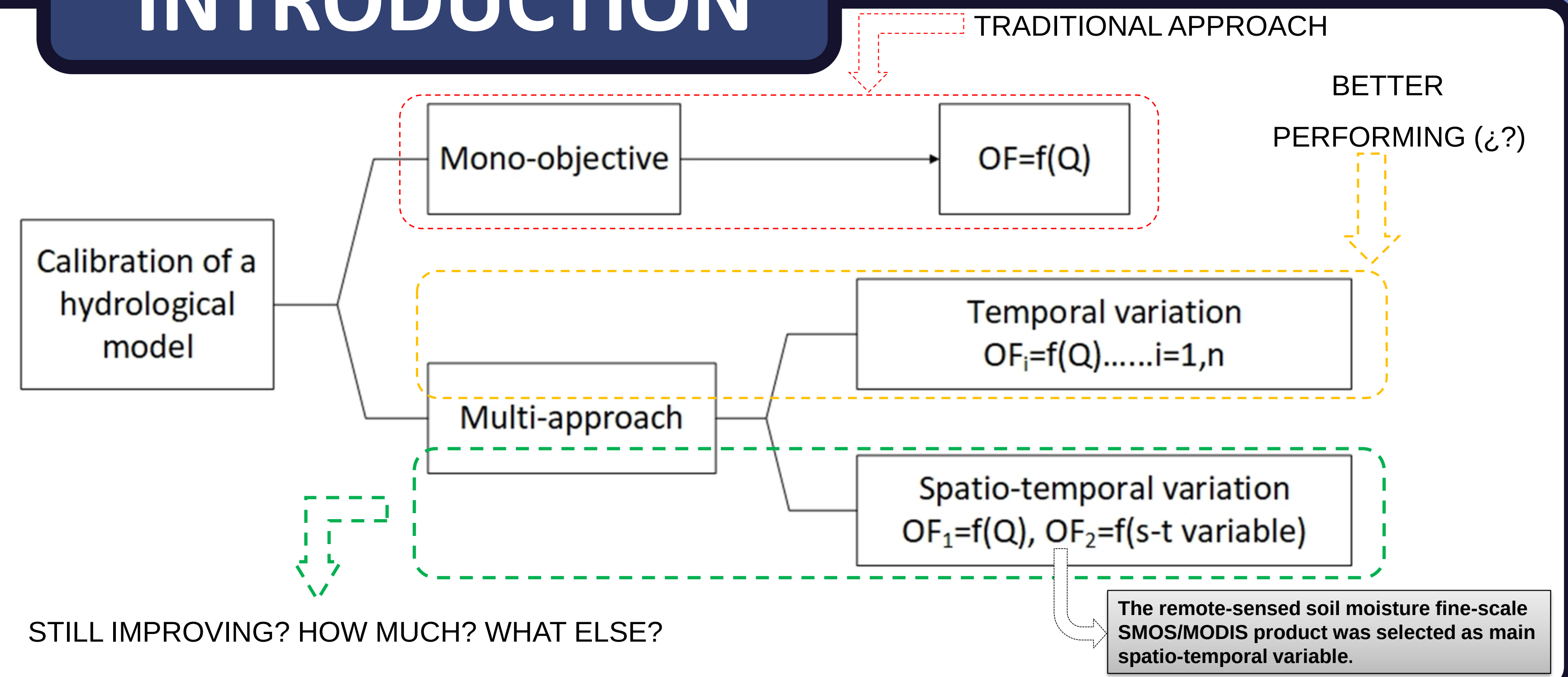
INTRODUCTION



TRADITIONAL APPROACH

BETTER PERFORMING (¿?)

Calibration of a hydrological model

Mono-objective → OF=f(Q)

Multi-approach

Temporal variation $OF_i=f(Q)$……i=1,n

Spatio-temporal variation $OF_1=f(Q)$, $OF_2=f(\text{s-t variable})$

The remote-sensed soil moisture fine-scale SMOS/MODIS product was selected as main spatio-temporal variable.

STILL IMPROVING? HOW MUCH? WHAT ELSE?

CALIBRATION APPROACHES

Configuration 1

–> Mono-objective calibration using SCE-UA

-> Main state variable: Flow at the catchment outlet point (Q)

-> Objective-function: Kling-Gupta Efficiency (KGE)

Common characteristics

-> Warm-up period: 2008-2009

-> Calibration period: 2010-2012

-> Validation period: 2013-2015

-> 24 parameters (9 hydrological and 15 vegetation)

Configuration 2

–> Multi-objective calibration using MOSCEM-UA

-> Main state variable: Flow at the catchment outlet point (Q)

-> Objective-functions: Kling-Gupta Efficiency (KGE) and Balance Error (BE)

Configuration 3

–> Multi-objective calibration using MOSCEM-UA

-> State variable: Flow at the catchment outlet point (Q) and **remote-sensed** soil moisture (SM).

-> Objective-functions: Kling-Gupta Efficiency (KGE) and Spatial function to evaluate soil moisture (SME**).

****STE**

–> It is a function to evaluate the performance of the simulated soil moisture compared to the observed soil moisture, composed by two parts:

1) KGE index between simulated and observed soil moisture pixel by pixel

2) a metric based on the similarity between the first five spatial principal components of simulated and observed soil moisture (EOF methodology);

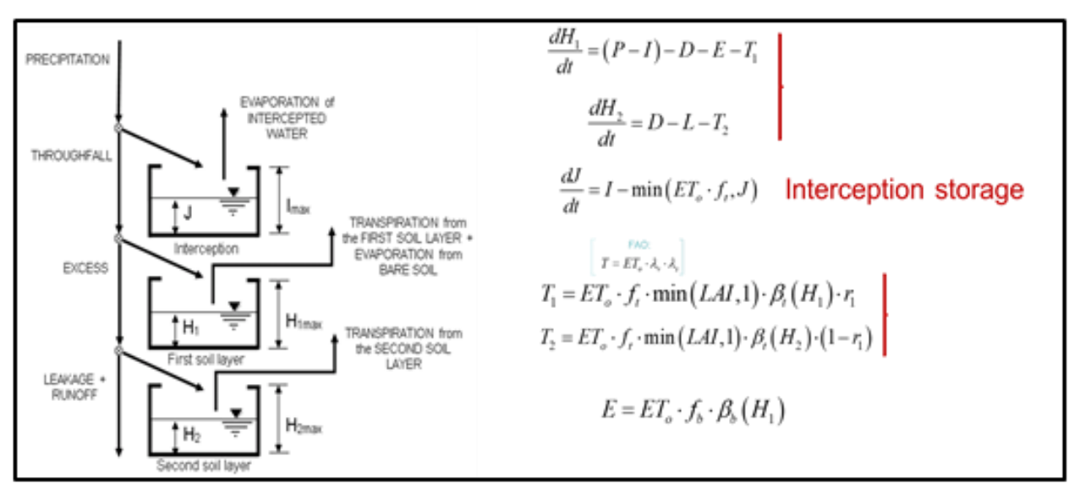
$$STE = \frac{P_1 + P_2}{2}$$

$$P_1 = \frac{\sum_{np=1}^{\#pixels}[KGE(sm_{obs}\&sm_{sim};\forall\, KGE \geq threshold)]}{total\ number\ of\ pixels}$$

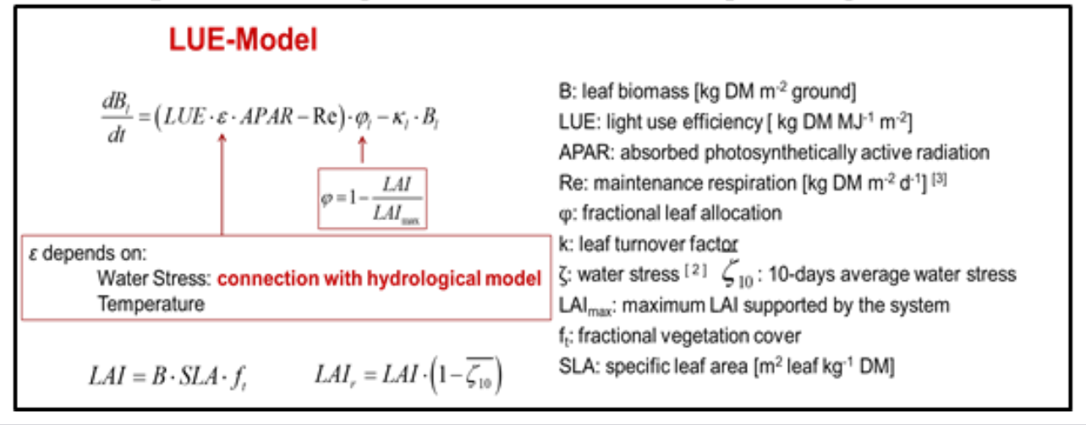
$$P_2 = \frac{\sum_{pc=1}^{5}[KGE(EOF - loadings_{obs}\ \&\ EOF - loadings_{sim})]}{5}$$

MODELS AND ALGORITHMS

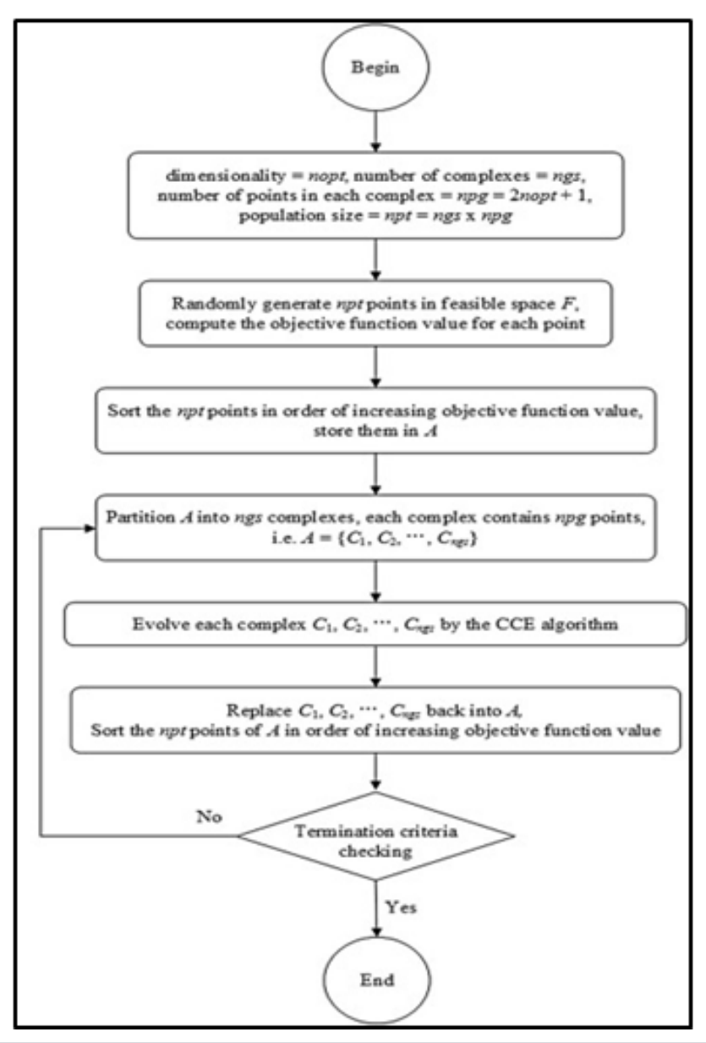
HYDROLOGICAL MODEL (TETIS)



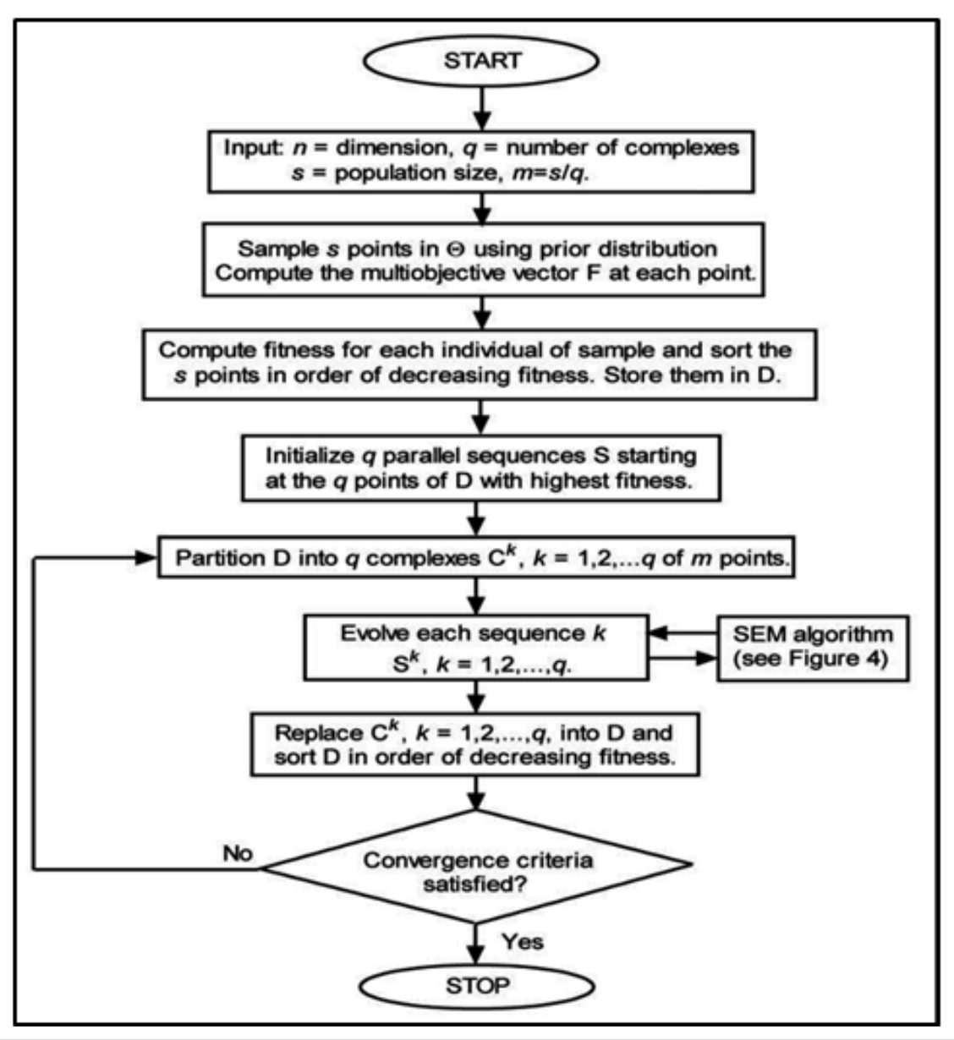
VEGETATION DYNAMIC MODEL



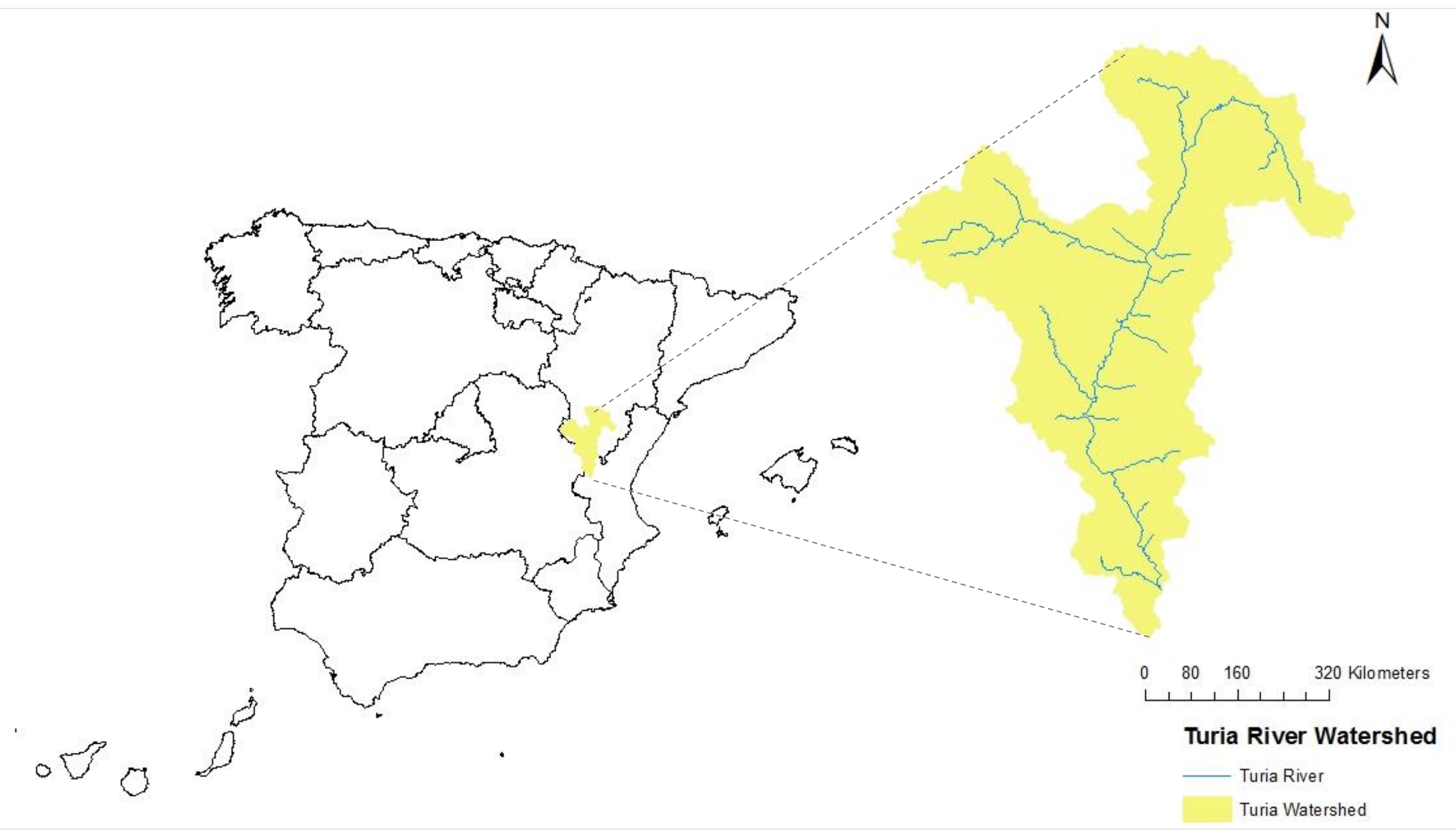
SCE-UA



MOSCEM-UA



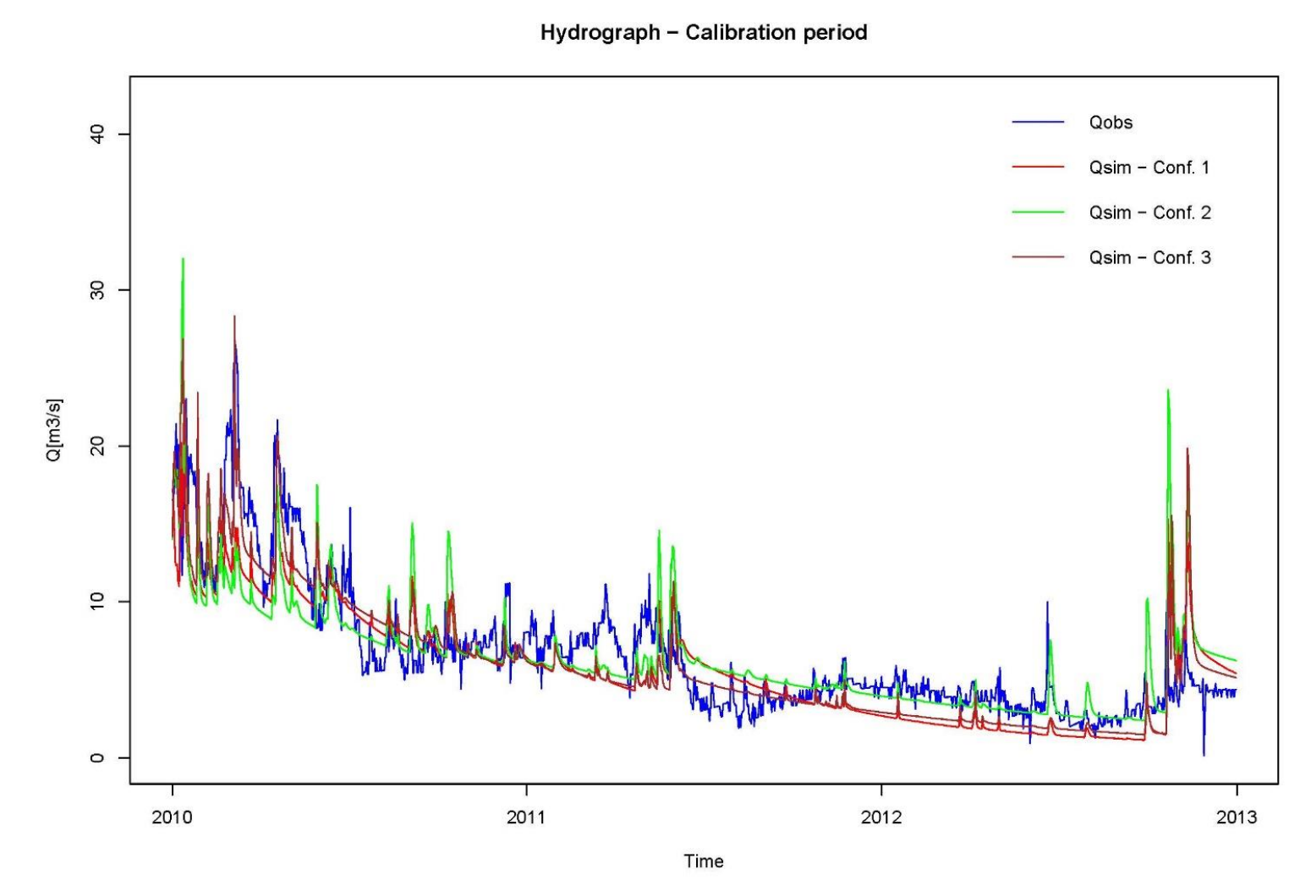
STUDY CASE

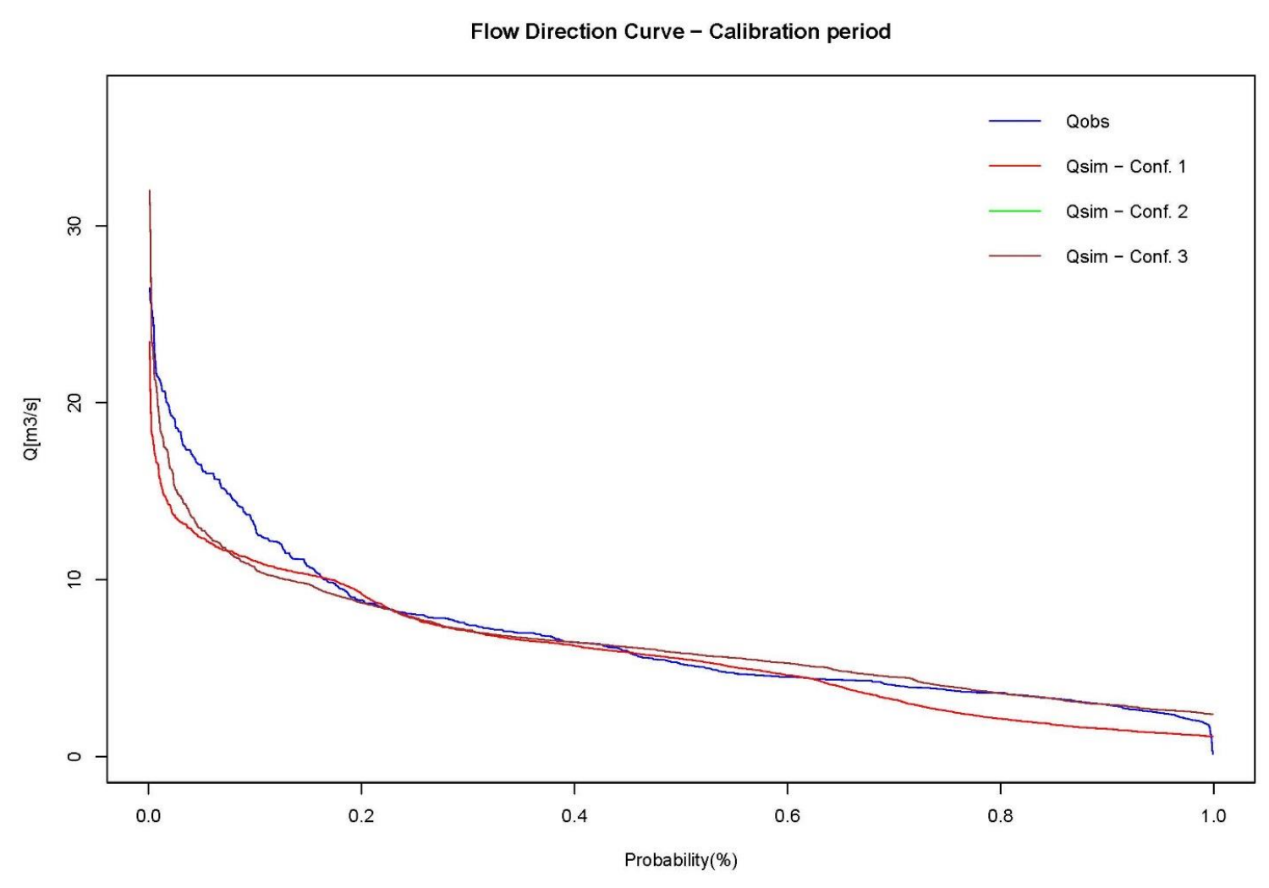


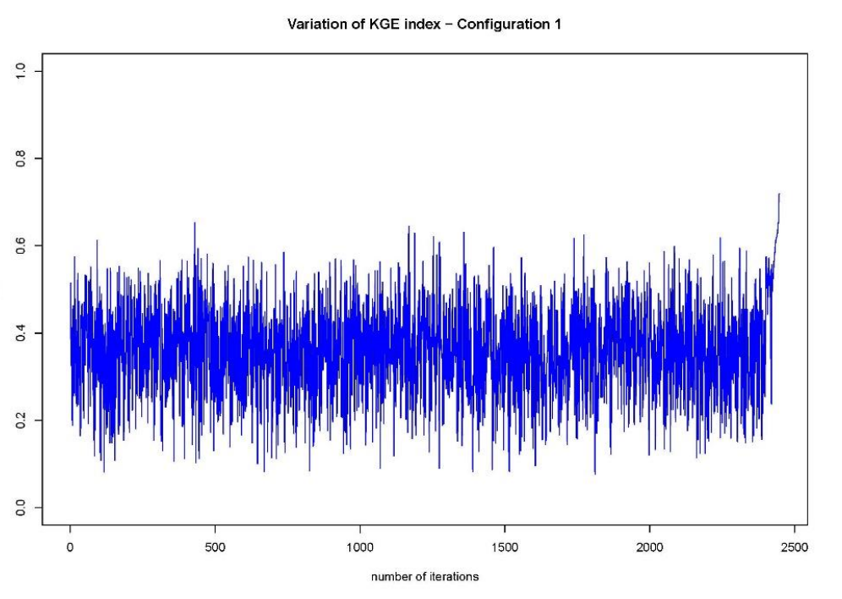
CHARACTERISTICS

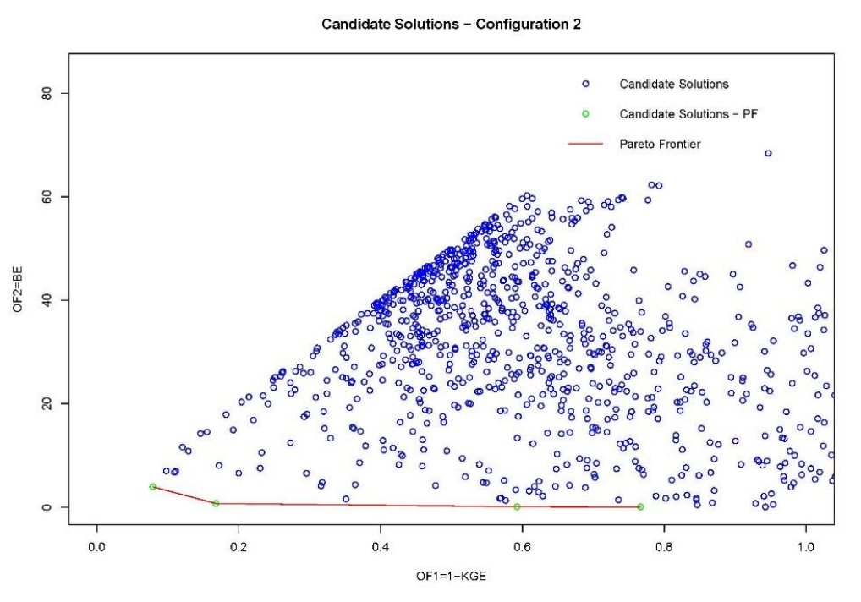
- Drainage length = 449.61 km
- Area = 4295 km^2
- Gauges = 93
- Temperature stations = 93
- ET stations = 105
- Radiation Stations = 13
- Reference period=2010-2015
- Regions:
-> Comunidad Valenciana
-> Castilla la Mancha
-> Aragón

RESULTS


Hydrograph – Calibration period


Flow Direction Curve – Calibration period


Variation of KGE index – Configuration 1


Candidate Solutions – Configuration 2

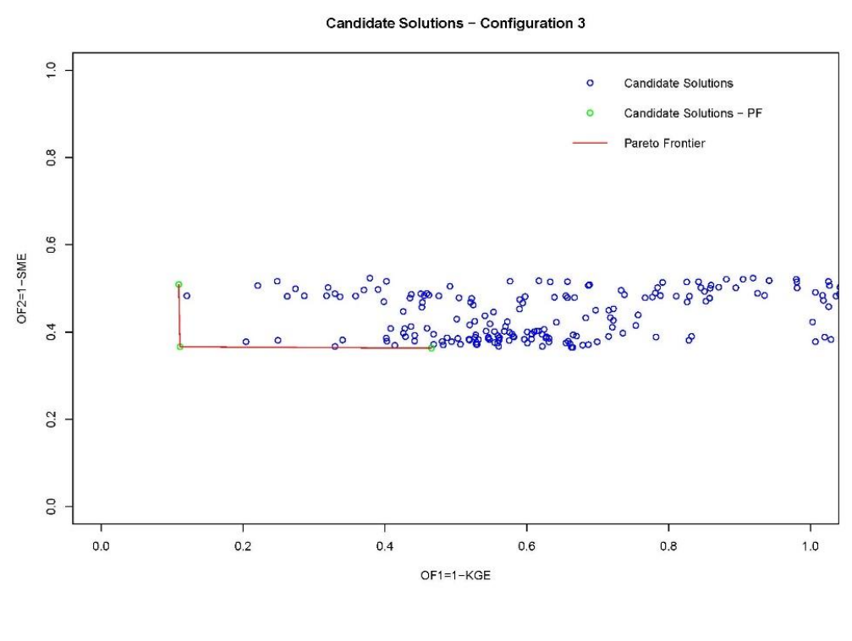
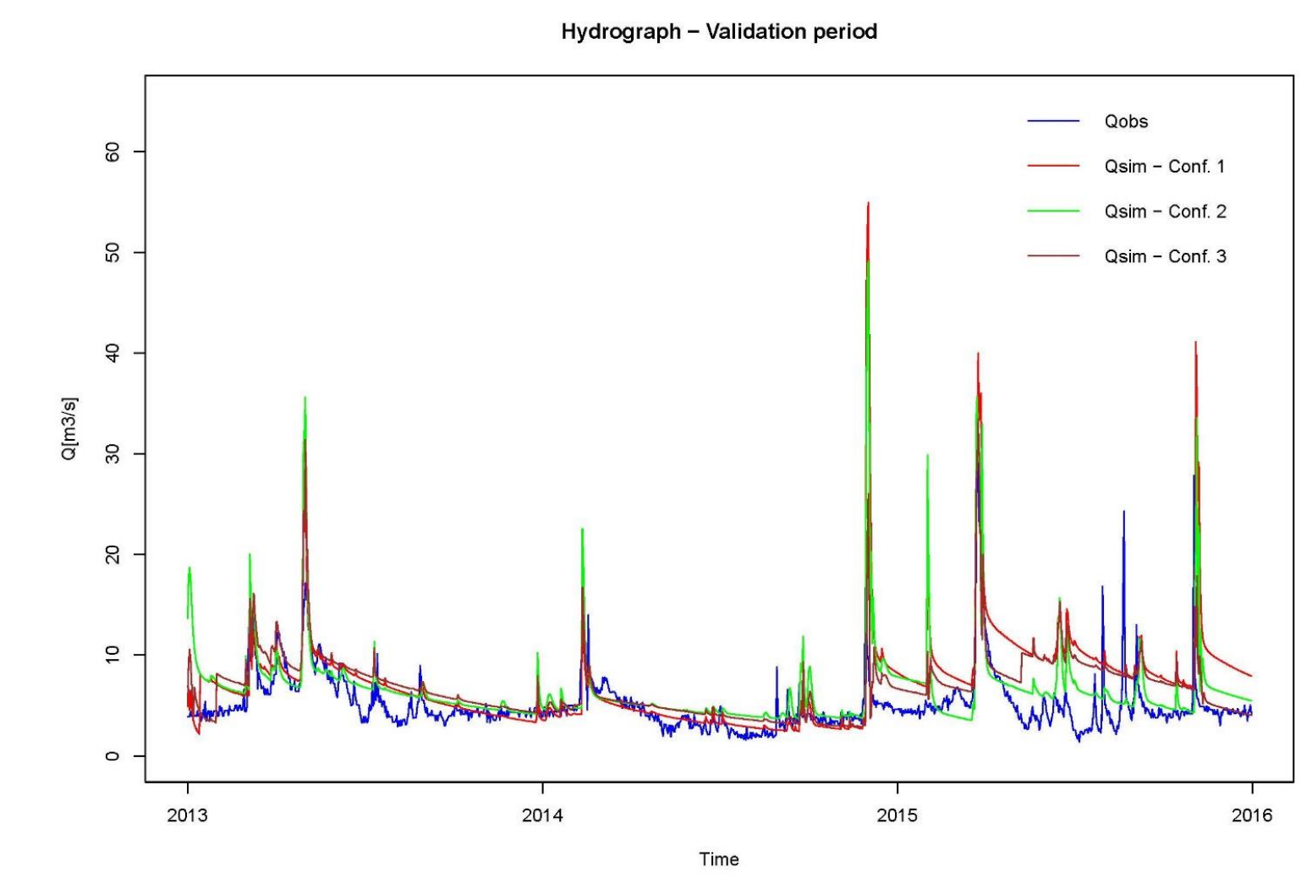

Candidate Solutions – Configuration 3

Table 1. Performance of metrics for the three approaches in calibration and validation periods

	Configuration 1	Configuration 2	Configuration 3
Calibration type	Mono-Objective	Multi-Objective	Multi-Objective
Objective-Function 1	KGE	KGE	KGE
Objective-Function 2	-	BE	SME
State Variable	Q	Q/Q	Q/SM
State Variable Type	Temporal	Temporal/Temporal	Temporal/Spatio-Temporal
Calibration results	KGE=0.7187	KGE=0.7675 BE=8.3444	KGE=0.8889 SME=0.6339
Validation results	KGE=0.1011	KGE=0.3182 BE=30.60	KGE=0.5168 SME=0.5836
Result variations	ΔKGE=0.6176 (-)	ΔKGE=0.4493(-) ΔBE=22.2556(+)	ΔKGE=0.3721(-) ΔSME=0.0503(-)


Hydrograph – Validation period

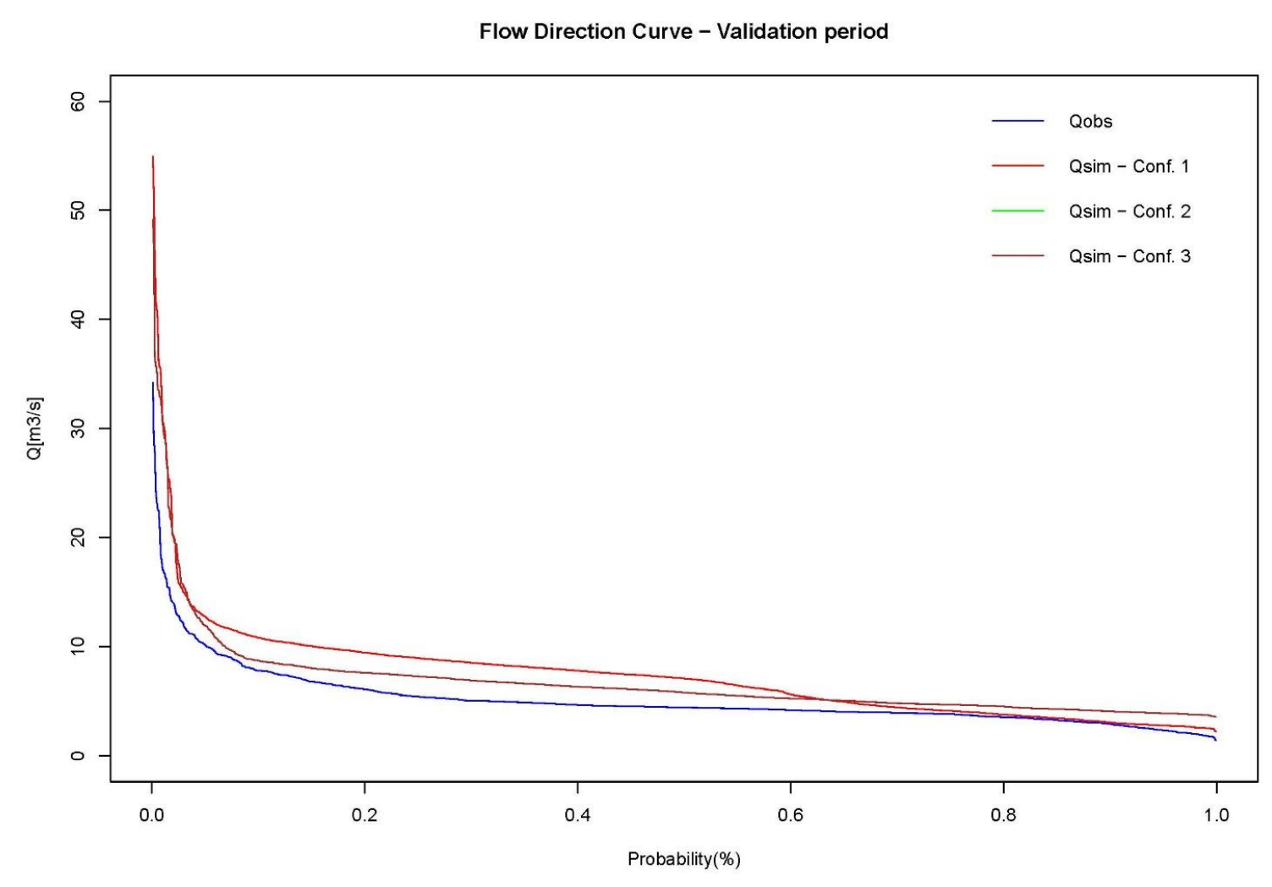

Flow Direction Curve – Validation period

Table 2. Characteristics of the three calibration configurations for calibration period

Calibration period (01/01/2010 - 31/12/2012)			
Characteristic	**Configuration 1**	**Configuration 2**	**Configuration 3**
Maximum observed discharge [m3/s]	26.491	26.491	26.491
Maximum simulated discharge [m3/s]	23.4401	32.0023	28.325
Observed peak time	08/03/2010	08/03/2010	08/03/2010
Simulated peak time	14/01/2010	13/01/2010	07/03/2010
Peak time error	53	54	1
Observed volume [Hm3]	698502	698502	698502
Simulated volume [Hm3]	606136.2	673262.8	639267.3
Observed Q95	16.1635	16.1635	16.1635
Simulated Q95	12.333	12.77165	14.56495
Observed Q50	5.218	5.218	5.218
Simulated Q50	5.5349	5.8498	5.0376

Table 3. Characteristics of the three calibration configurations for validation period

Validation period (01/01/2013 - 31/12/2015)			
Characteristic	**Configuration 1**	**Configuration 2**	**Configuration 3**
Maximum observed discharge [m3/s]	34.206	34.206	34.206
Maximum simulated discharge [m3/s]	54.9366	49.1602	33.4437
Observed peak time	25/03/2015	25/03/2015	25/03/2015
Simulated peak time	03/12/2014	05/12/2014	26/03/2015
Peak time error	112	110	-1
Observed volume [Hm3]	530081.1	530081.1	530081.1
Simulated volume [Hm3]	756652.4	692070.8	707673.8
Observed Q95	10.0714	10.0714	10.0714
Simulated Q95	12.682	11.88539	10.91004
Observed Q50	4.412	4.412	4.412
Simulated Q50	7.0652	5.797	6.5004

CONCLUSIONS

I. Multi-objective approaches (configurations two and three) lead to better model performance. Graphically is possible to support this phrase by the hydrographs and Flow Direction Curves. In Table 2 and Table 3 is also possible to visualize closer values to observed data of Q95, Q50, maximum discharge and accumulated volume.

II. The visualization of the Pareto set allows to identify whether all objective functions can be simultaneously optimized and pinpoints the optimal set of parameters, assisting thus the decision making process.

III. The differences among the three approaches are more evident during the validation period, pointing out that the use of multiple objective functions leads to more realistic parameter values.

IV. Even though challenging, spatio-temporal data, in particular soil moisture, must be explored as relevant source of information to calibrate process-based models in future applications

V. The SMOS/MODIS remote-sensed fine-scale soil moisture data is consistent with observed discharge and the combination of both shows the best results(Table 1).

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