HARMONIOUS
uas for environmental monitoring

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

iiama
Instituto de Ingeniería del Agua y Medio Ambiente

HARMONIOUS

UAS Techniques for Environmental Monitoring

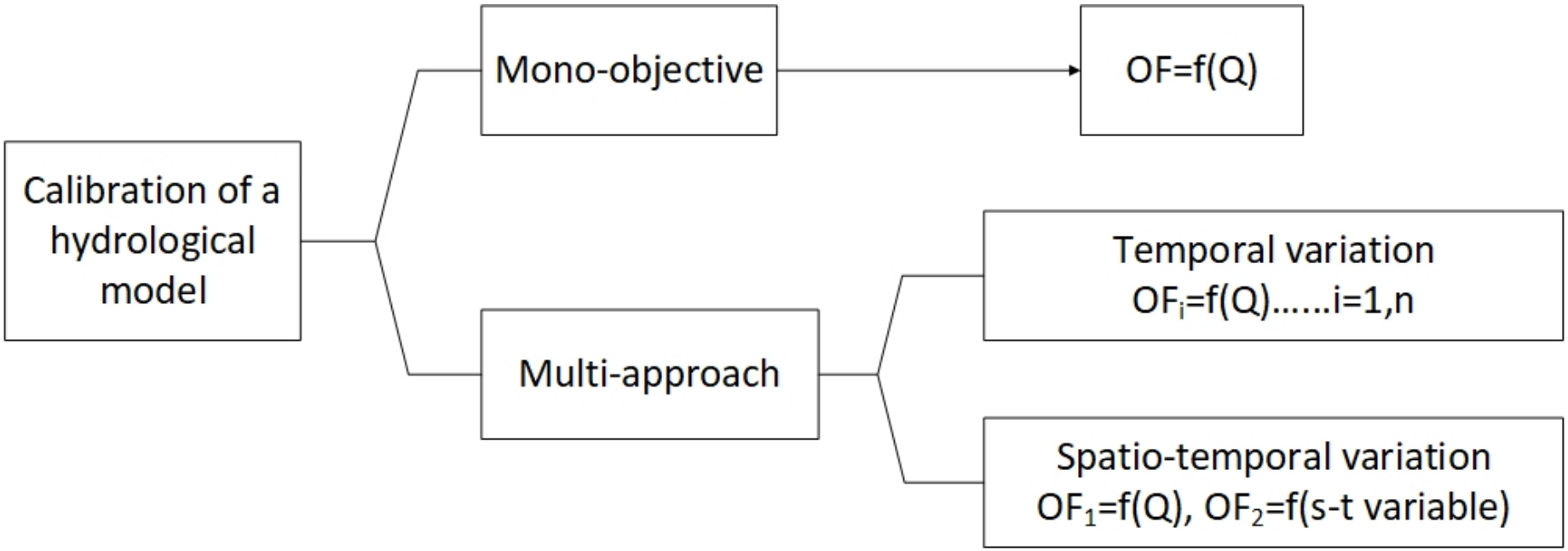
"On the use of remote sensed soil moisture data in spatio-temporal model calibration for a Mediterranean catchment"

Carlos Echeverría
Félix Francés

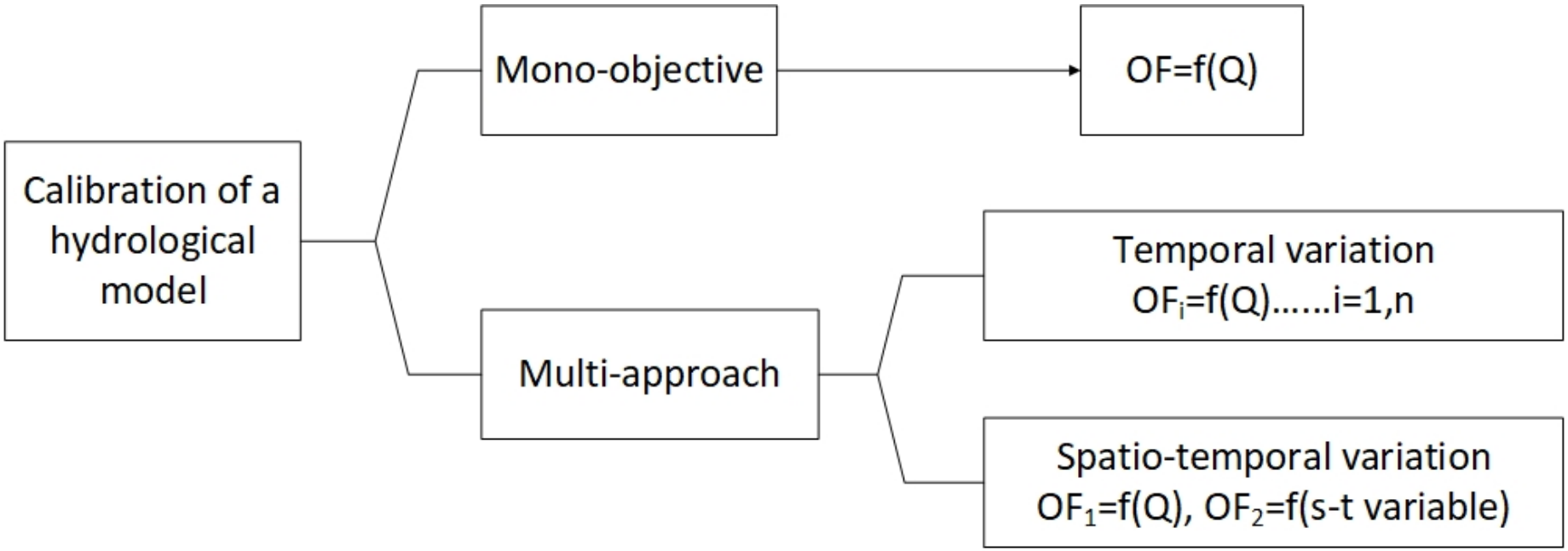
cost
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Funded by the Horizon 2020 Framework Programme of the European Union

INTRODUCTION



INTRODUCTION



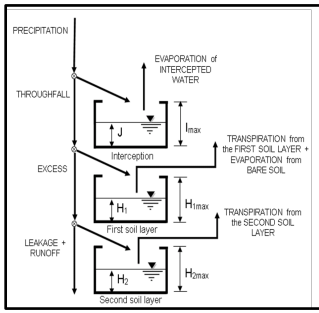
……. **remote-sensed** soil moisture…….

OBJECTIVE

Evaluation of the performance of hydrological modelling using a multi-objective algorithm including remote-sensed soil moisture as a state variable, with projection for use in ungauged basins.

PROPOSED METHODOLOGY - RESOURCES

HYDROLOGICAL MODEL (TETIS)



$$\frac{dH_1}{dt} = (P - I) - D - E - T_1$$

$$\frac{dH_2}{dt} = D - L - T_2$$

$$\frac{dJ}{dt} = I - \min(ET_o \cdot f_t, J)$$ Interception storage

$$T_1 = ET_o \cdot f_t \cdot \min(LAI, 1) \cdot \beta_t(H_1) \cdot r_1$$

$$T_2 = ET_o \cdot f_t \cdot \min(LAI, 1) \cdot \beta_t(H_2) \cdot (1 - r_1)$$

$$E = ET_o \cdot f_b \cdot \beta_b(H_1)$$

VEGETATION DYNAMIC MODEL

LUE-Model

$$\frac{dB_t}{dt} = (LUE \cdot \varepsilon \cdot APAR - \mathrm{Re}) \cdot \varphi_t - \kappa_t \cdot B_t$$

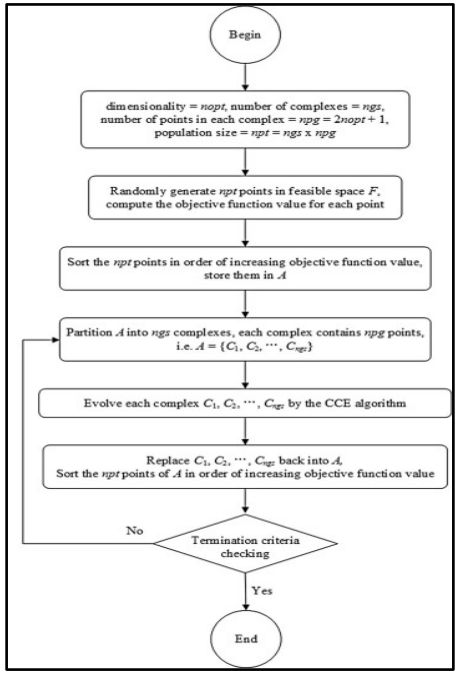
$$\varphi = 1 - \frac{LAI}{LAI_{max}}$$

ε depends on:
Water Stress: **connection with hydrological model**
Temperature

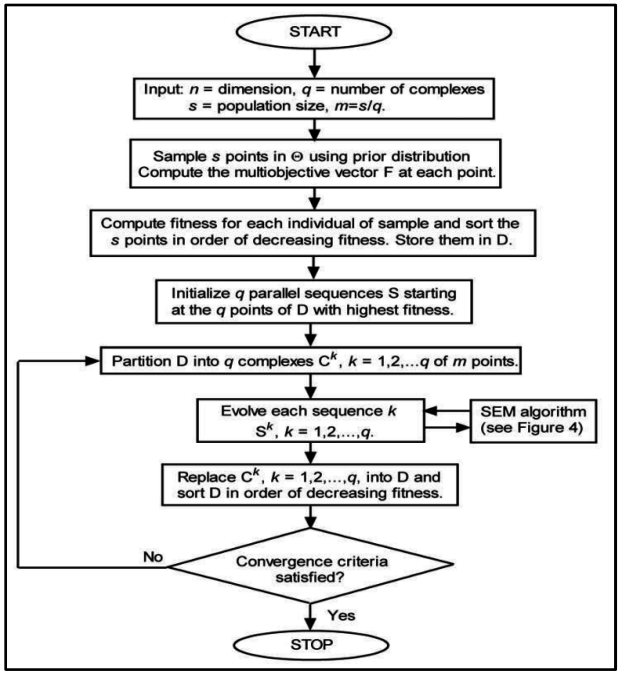
$$LAI = B \cdot SLA \cdot f_t \qquad LAI_r = LAI \cdot (1 - \overline{\zeta_{10}})$$

B: leaf biomass [kg DM m^{-2} ground]
LUE: light use efficiency [kg DM MJ^{-1} m^{-2}]
APAR: absorbed photosynthetically active radiation
Re: maintenance respiration [kg DM m^{-2} d^{-1}] [3]
φ: fractional leaf allocation
k: leaf turnover factor
ζ: water stress [2] ζ_{10} : 10-days average water stress
LAI_{max}: maximum LAI supported by the system
f_t: fractional vegetation cover
SLA: specific leaf area [m^2 leaf kg^{-1} DM]

SCE-UA

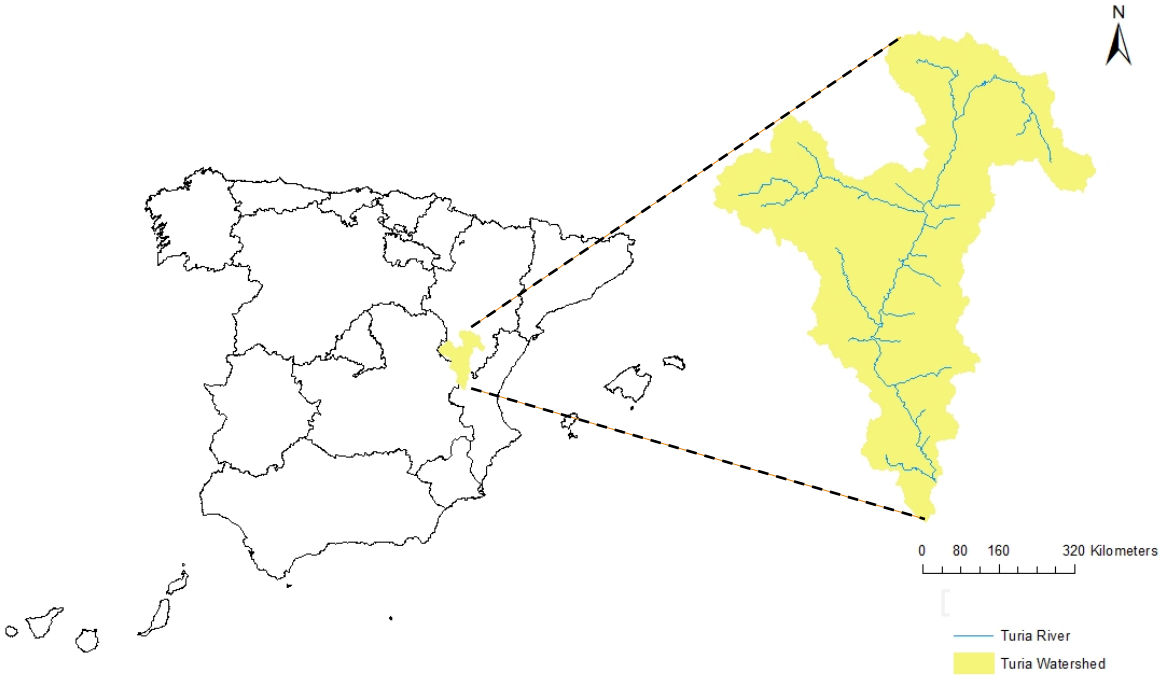


MOSCEM-UA



PROPOSED METHODOLOGY - STUDY AREA

UPPER TURIA RIVER WATERSHED



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

PROPOSED METHODOLOGY - SATELLITE DATA

Soil moisture maps covering the Iberian Peninsula

-> Temporal resolution: two maps per day (ascending – descending)

-> Temporal coverage: 5 years (since January 2010 to December 2015)

-> Downscaling: Brightness Temperature(ESA SMOS) + LST (NASA Terra/Aqua MODIS) + NDVI (NASA Terra/Aqua MODIS)

-> Free access by SMOS-BEC website (http://bec.icm.csic.es/)

-> Spatial resolution: 1 km

-> New version provides soil moisture estimation independently of cloud cover.

PROPOSED METHODOLOGY – ALTERNATIVES

Configuration 1

–> Mono-objective calibration using SCE-UA

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

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

-> 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)

-> Warm-up period: 2008-2009

-> Calibration period: 2010-2012

-> Validation period: 2013-2015

-> 24 parameters (9 hydrological and 15 vegetation)

PROPOSED METHODOLOGY – ALTERNATIVES

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).

-> Warm-up period: 2008-2009

-> Calibration period: 2010-2012

-> Validation period: 2013-2015

-> 24 parameters (9 hydrological and 15 vegetation's)

SME

–> 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);

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

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

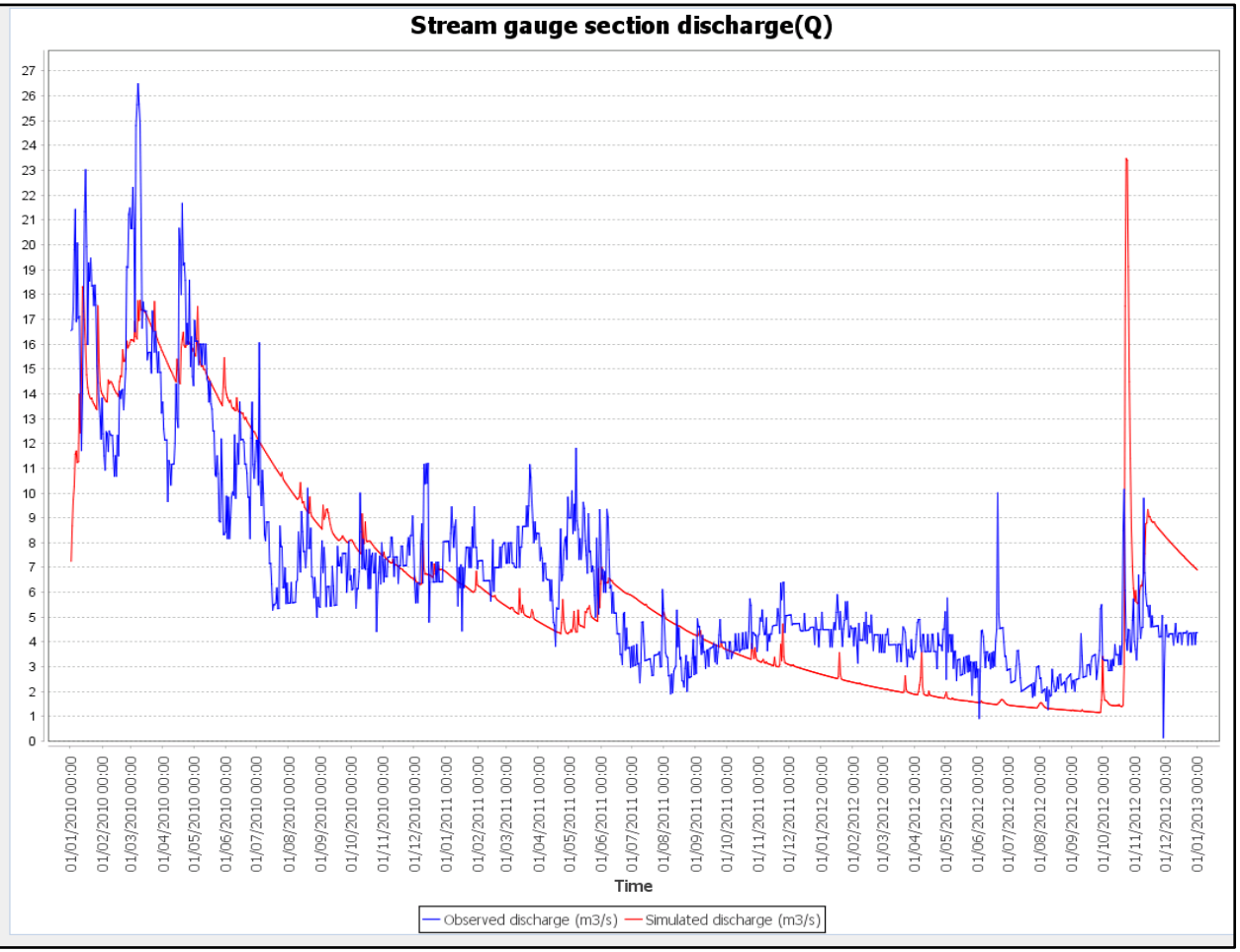
$$P_2 = \frac{\sum_{i=1}^{5} [KGE(EOF - loadings_{obs}\ \&\ EOF - loadings_{sim})]}{5}$$

RESULTS: CONFIGURATION 1 - CALIBRATION

-> Main state variable: Flow at the catchment outlet point (Q) **; Calibration period: KGE= 0.8123**

-> Mono-objective calibration using SCE-UA (Convergence criteria = ΔFO≤0.001, Number of iterations= 1325)

Main Event characteristics	
Max. obs. discharge (m3/s)	26.491
Max. sim. discharge (m3/s)	23.472
RMSE	2.744
Observed peak time	07/03/2010 23:59
Simulated peak time	23/10/2012 23:59
Peak time error (dt)	961
Observed volume (Hm3)	637.319
Simulated volume (Hm3)	611.474
Volume error (%)	-4.055
Nash and Sutcliffe efficience	0.5958
Drainage area (km2)	4299.650

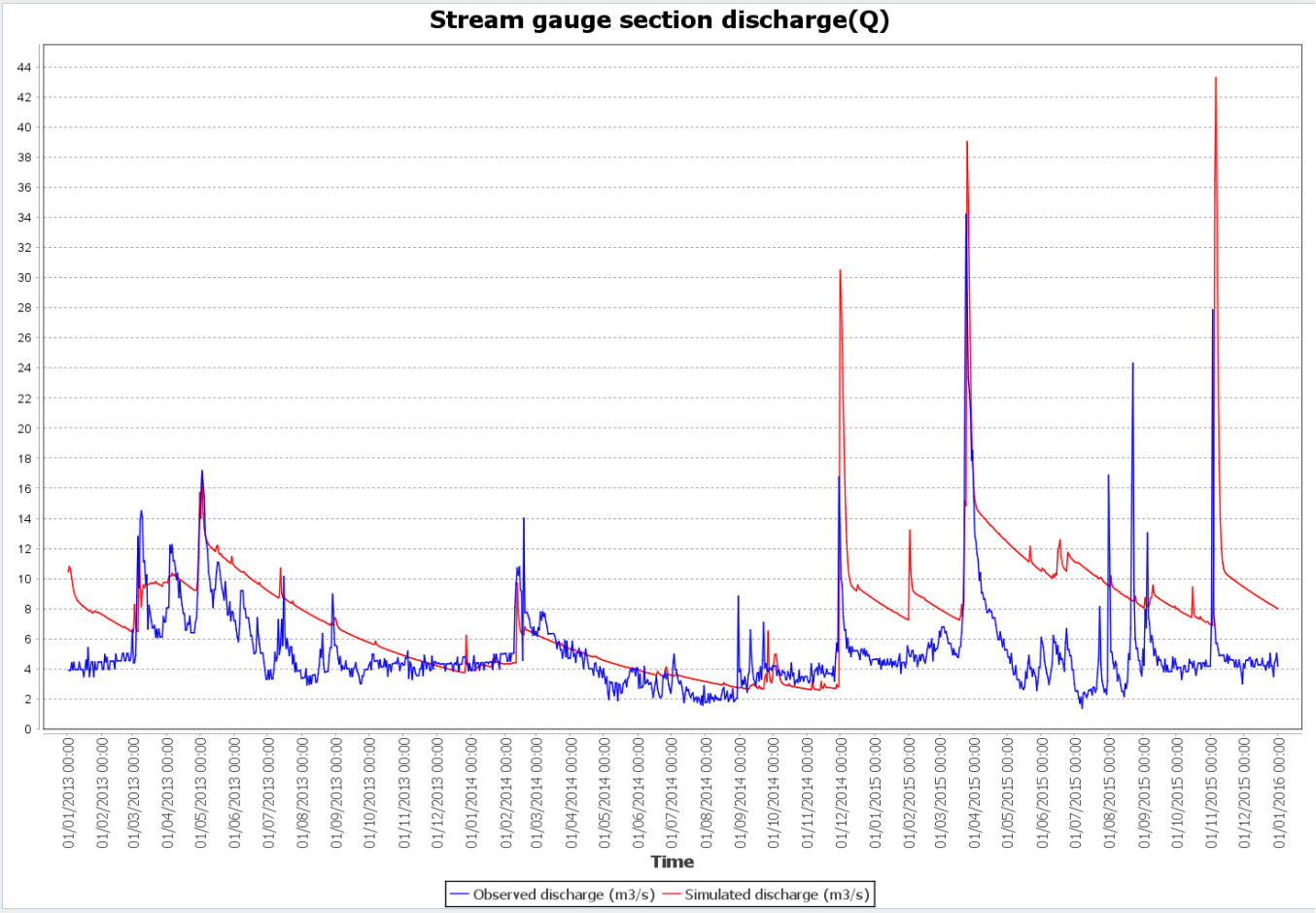


RESULTS: CONFIGURATION 1 - VALIDATION

-> Main state variable: Flow at the catchment outlet point (Q) ; **Calibration period: KGE= 0.8123**

-> **Validation period: KGE= 0.10112**

Main Event characteristics	
Max. obs. discharge (m3/s)	34.206
Max. sim. discharge (m3/s)	43.290
KGE	4.282
Observed peak time	24/03/2015 23:59
Simulated peak time	05/11/2015 23:59
Peak time error (dt)	226
Observed volume (Hm3)	484.092
Simulated volume (Hm3)	714.091
Volume error (%)	47.511
Nash and Sutcliffe efficience	-1.1358
Drainage area (km2)	4299.650



RESULTS: CONFIGURATION 2 – CALIBRATION (PF)

PARETO FRONT

Configuration 2

-> State variable: Flow at the catchment outlet point (Q): F1=KGE, F2=BE(%)

–> Multi-objective calibration using MOSCEM-UA

Initial population (s) = 1000 points

Number of complexes (q) = 50

Number of points per complex (m) = 20

New candidates points per complex (L) = 5

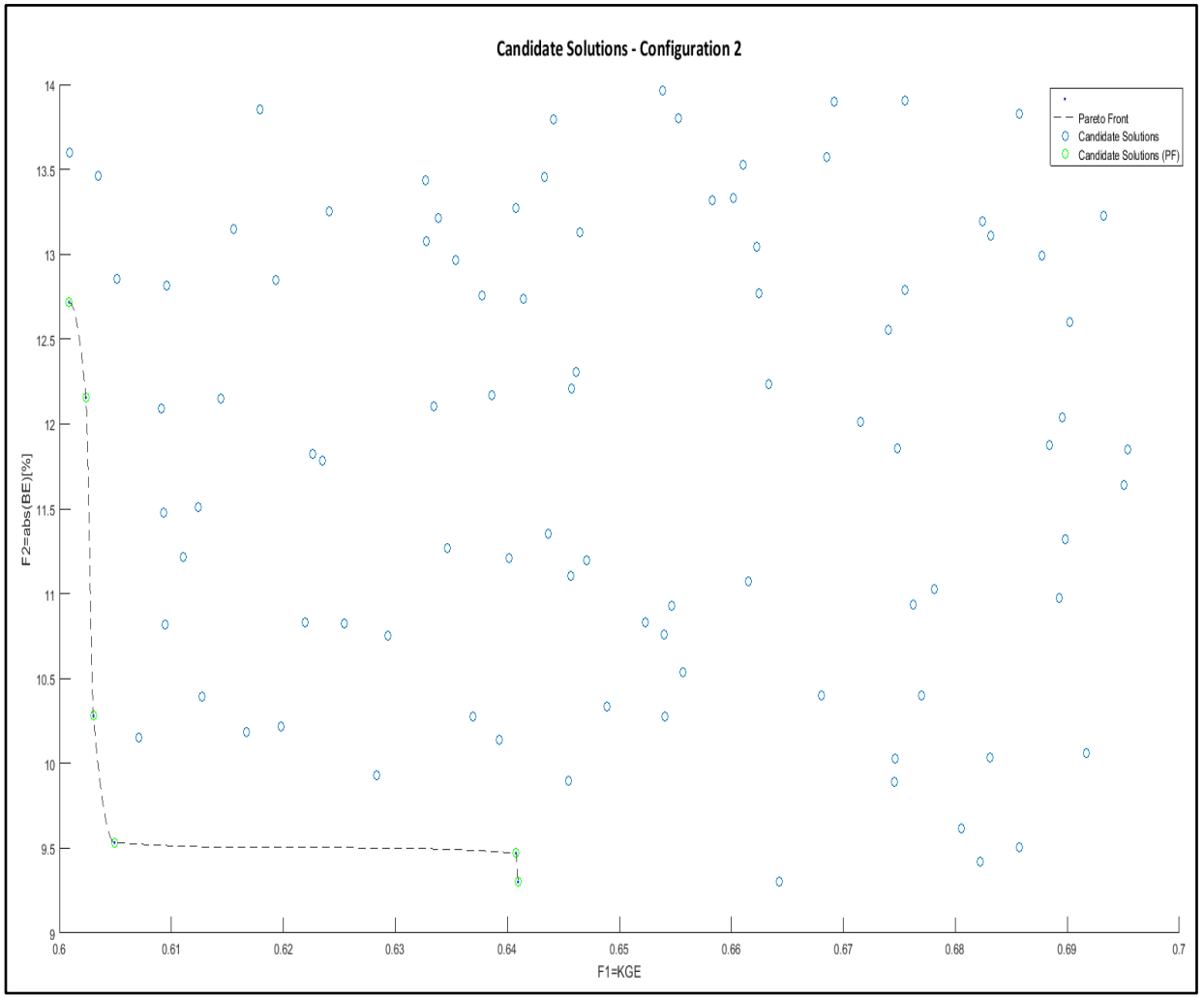
Number of iterations = 150

Candidate solutions = 97

Candidate solutions (Pareto Front) = 6

-> Chosen Candidate Solution

Calibration	Validation
KGE =	KGE =
BE=	BE =



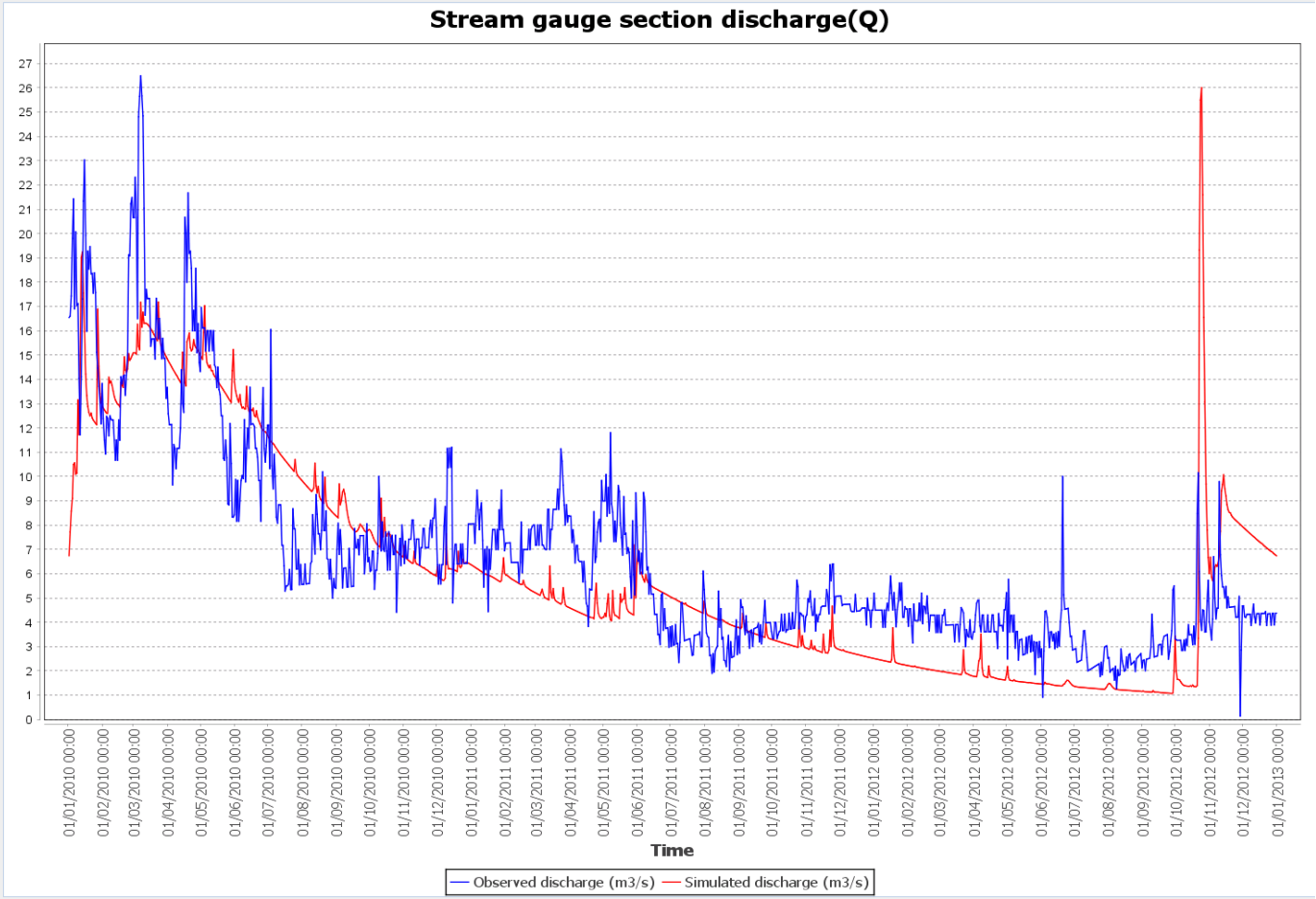
RESULTS: CONFIGURATION 2 – CALIBRATION (HG)

-> State variable: Flow at the catchment outlet point (Q): F1=KGE, F2=BE(%) ; Multi-objective calibration using MOSCEM-UA

-> **Calibration: KGE=0.7701 & BE=9.039**

Main Event characteristics

Max. obs. discharge (m3/s)	26.491
Max. sim. discharge (m3/s)	26.001
RMSE	2.853
Observed peak time	07/03/2010 23:59
Simulated peak time	24/10/2012 23:59
Peak time error (dt)	962
Observed volume (Hm3)	637.319
Simulated volume (Hm3)	579.712
Volume error (%)	-9.039
Nash and Sutcliffe efficience	0.5632
Drainage area (km2)	4299.650



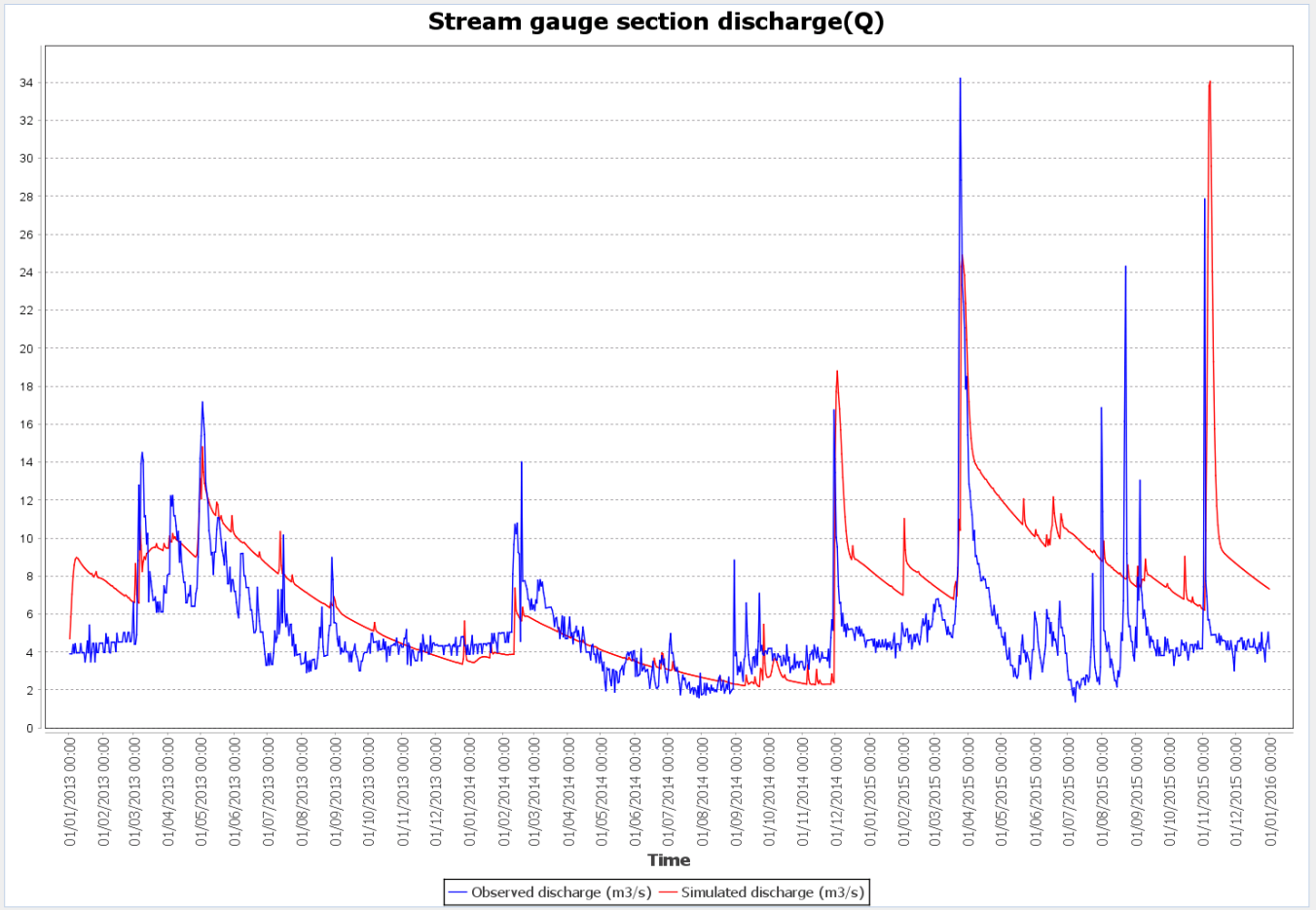
RESULTS: CONFIGURATION 2 – VALIDATION (HG)

-> State variable: Flow at the catchment outlet point (Q): F1=KGE, F2=BE(%) ; Multi-objective calibration using MOSCEM-UA

-> Calibration: KGE=0.7701 & BE=9.039; **Validation: KGE=0.215 & BE=37.684**

Main Event characteristics

Max. obs. discharge (m3/s)	34.206
Max. sim. discharge (m3/s)	34.041
RMSE	3.927
Observed peak time	24/03/2015 23:59
Simulated peak time	07/11/2015 23:59
Peak time error (dt)	228
Observed volume (Hm3)	484.092
Simulated volume (Hm3)	666.519
Volume error (%)	37.684
Nash and Sutcliffe efficience	-0.7970
Drainage area (km2)	4299.650



RESULTS: CONFIGURATION 3 – CALIBRATION (PF)

PARETO FRONT

Configuration 3

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

-> Multi-objective calibration using MOSCEM-UA

Initial population (s) = 1000 points

Number of complexes (q) = 50

Number of points per complex (m) = 20

New candidates points per complex (L) = 5

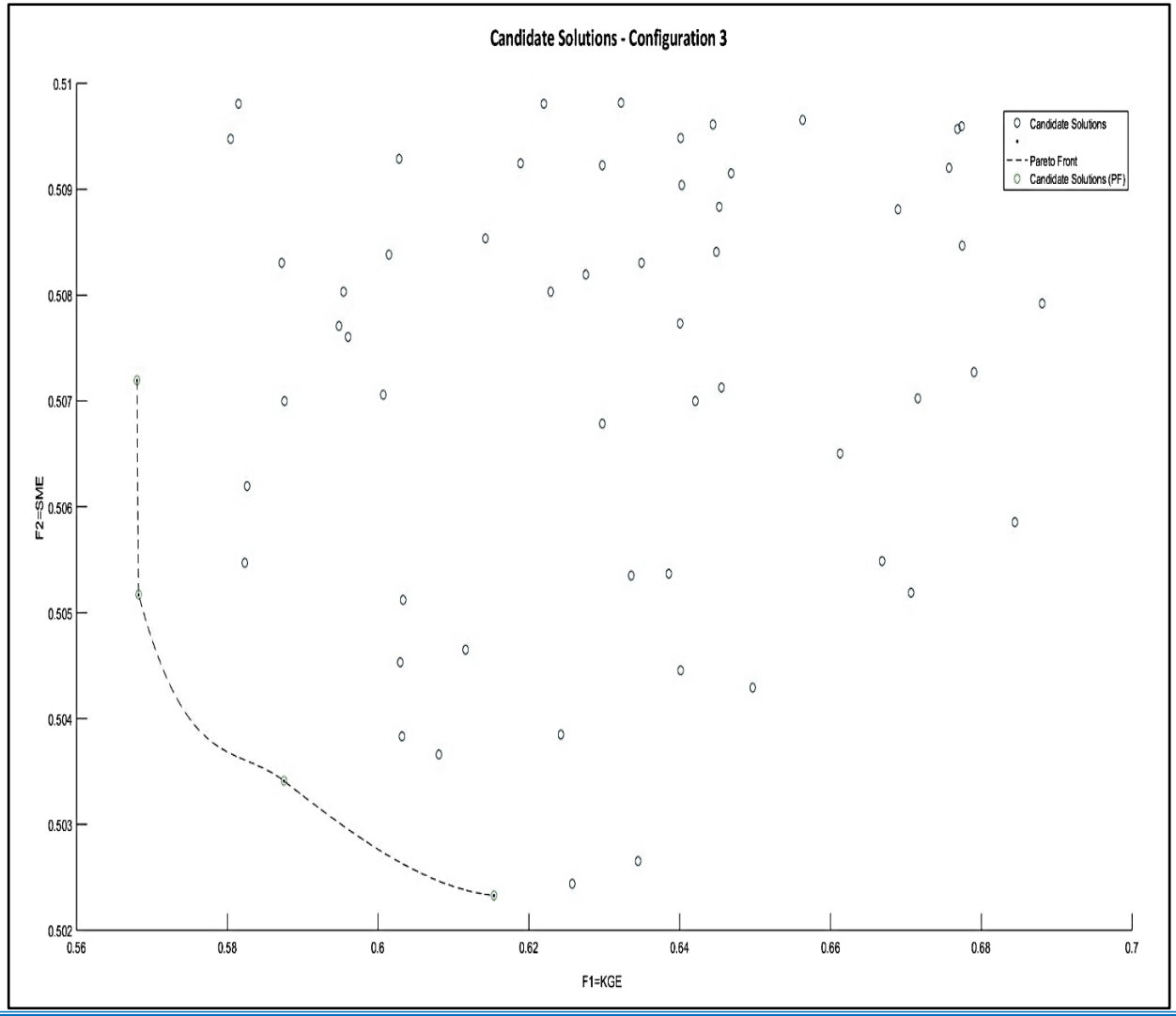
Number of iterations = 150

Candidate solutions = 59

Candidate solutions (Pareto Front) = 4

-> Chosen Candidate Solution

Calibration	Validation
KGE =	KGE=
SME=	SME=

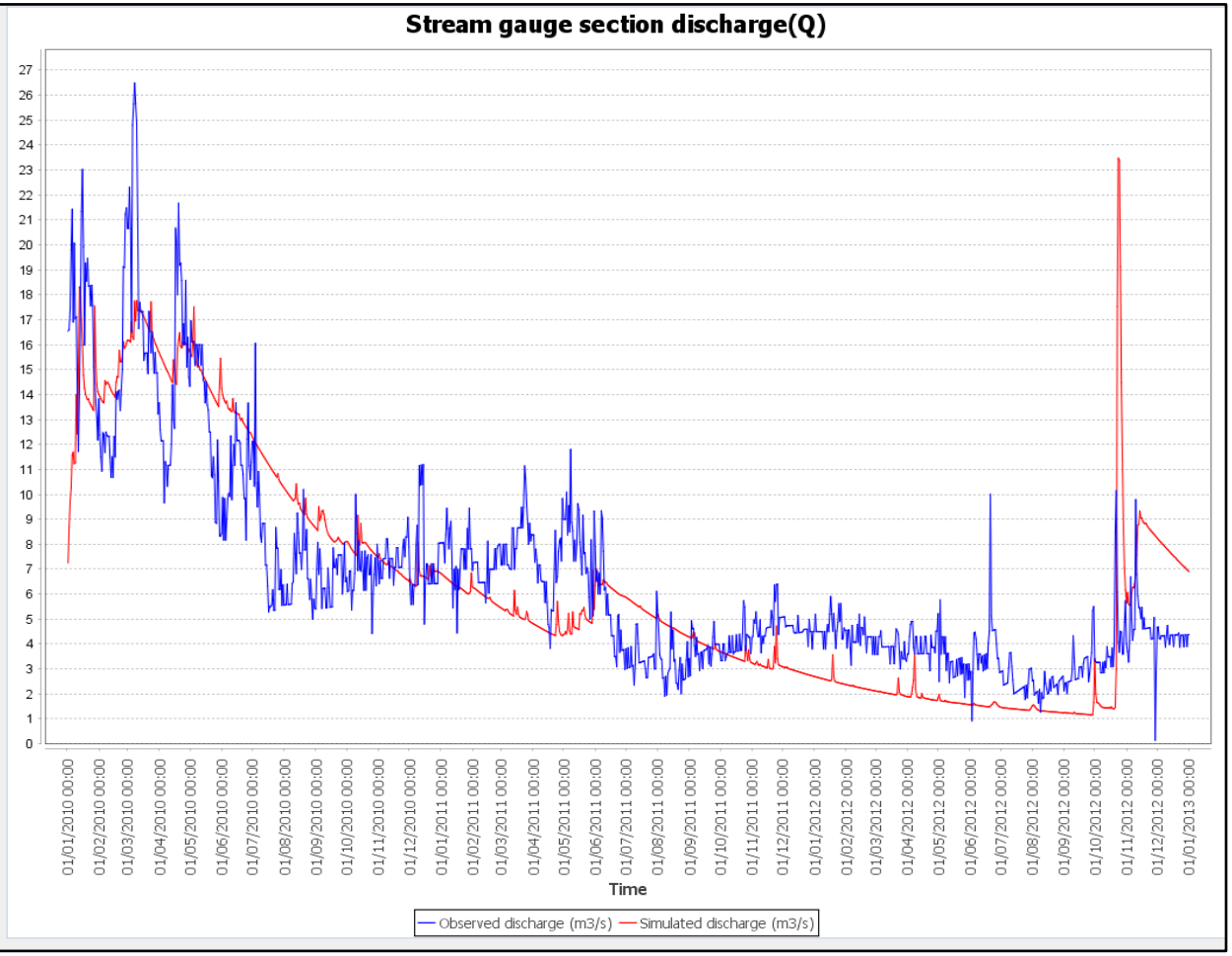


RESULTS: CONFIGURATION 3 – CALIBRATION (HG)

-> State variable: Flow at the catchment outlet point (Q) and **remote-sensed** soil moisture (SM); Multi-objective calibration using MOSCEM-UA

Calibration: KGE = 0.7321, SME= 0.5836

Main Event characteristics	
Max. obs. discharge (m3/s)	26.491
Max. sim. discharge (m3/s)	23.472
RMSE	2.744
Observed peak time	07/03/2010 23:59
Simulated peak time	23/10/2012 23:59
Peak time error (dt)	961
Observed volume (Hm3)	637.319
Simulated volume (Hm3)	611.474
Volume error (%)	-4.055
Nash and Sutcliffe efficience	0.5958
Drainage area (km2)	4299.650



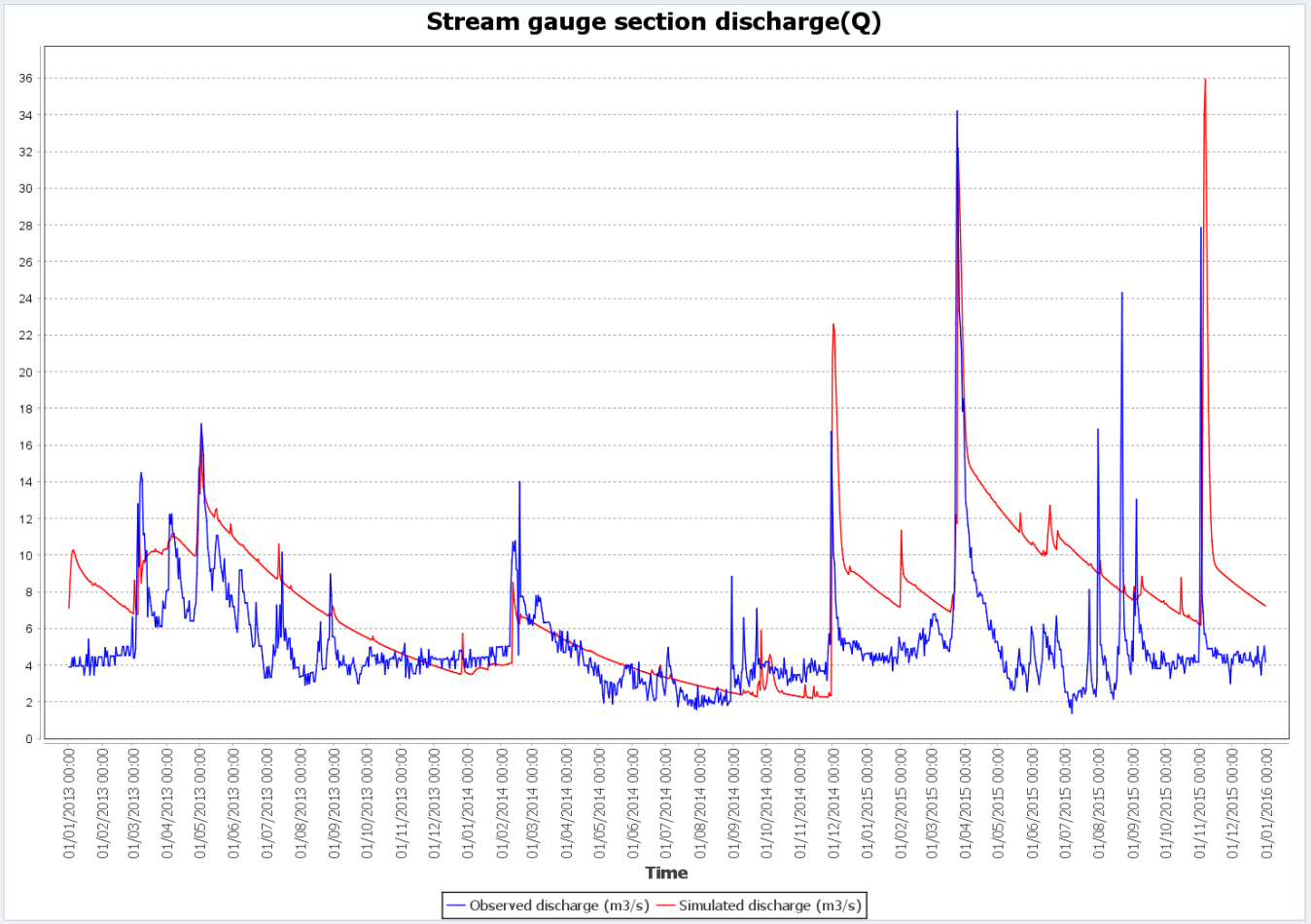
RESULTS: CONFIGURATION 3 – VALIDATION (HG)

-> State variable: Flow at the catchment outlet point (Q) and **remote-sensed** soil moisture (SM); Multi-objective calibration using MOSCEM-UA

Calibration: KGE = 0.7321, SME= 0.5836; **Validation: KGE = 0.62356, SME= 0.5321**

Main Event characteristics

Max. obs. discharge (m3/s)	34.206
Max. sim. discharge (m3/s)	35.939
RMSE	4.100
Observed peak time	24/03/2015 23:59
Simulated peak time	06/11/2015 23:59
Peak time error (dt)	227
Observed volume (Hm3)	484.092
Simulated volume (Hm3)	697.355
Volume error (%)	44.054
Nash and Sutcliffe efficience	-0.9588
Drainage area (km2)	4299.650



CONCLUSIONS

Calibration using a multi-approach configuration (in this case, with two temporal objective-functions) is possible to improve the performance of the model.

Multi-approach calibration, including spatio-temporal information improves the performance of the model even further, pointing out the higher reliability of the obtained parameter values when including spatio-temporal data (in this case, remote-sensed soil moisture) in the calibration model.

Even including spatial patterns implied less reduction in the temporal estimator, the spatio-temporal estimator presented little reduction in the validation step.

CONCLUSIONS

In the calibration period, the best results were obtained by the first configuration (only temporal information included), followed by the second configuration (multi-approach but with only temporal information included) and in the last position the third configuration (temporal and spatio-temporal information included).

Even though the performance of the first calibration approach was slightly better than the second and the third, the three calibration approaches provided satisfactory and similar results within the calibration period.

In the validation period, the best results were obtained by the third configuration, followed by the second configuration and in the last position the first configuration.

CONCLUSIONS

	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=f(KGE-EOF)
State Variable	T	T/T	T/S-T
Calibration results	KGE=0.8123	KGE=0.7701 BE=9.039	KGE=0.7321 SME=0.5836
Validation results	KGE=0.10112	KGE=0.2150 BE=37.684	KGE=0.62356 SME=0.5321
Result variations	ΔKGE=0.7118 (-)	ΔKGE=0.5551(-) ΔBE=28.645(+)	ΔKGE=0.10854(-) ΔSME=0.015(-)

THANK YOU FOR YOUR ATTENTION

Carlos Echeverría (carec@doctor.upv.es)
Félix Francés (ffrances@hma.upv.es