# A preliminary global assessment of under-catch of solid precipitation in Canales Basin (Sierra Nevada, Spain)

P. Jimeno, M. Pegalajar, **D. Pulido-Velázquez**, AJ Collados-Lara,
Eulogio Pardo. Spanish Geological Survey.
Spanish Geological Survey, IGME

1. INTRODUCTION: Under-catching phenomenon

2. MATERIAL & METHOD (Global assessment of under-catching)

   2.0. Location of the study area and data (s/t resolution and **LONG periods**)

   2.A. Geostatistical estimation of climatic fields (P & T). Hypothesis

   2.B. Automatic calibration of conceptual-hydrological balance model (snow $\subset$):

   - **Optimization algorithm** (Automatic calibration)

3. RESULTS

   3.1 Best calibration algorithm = f(longitude of the temporal period)

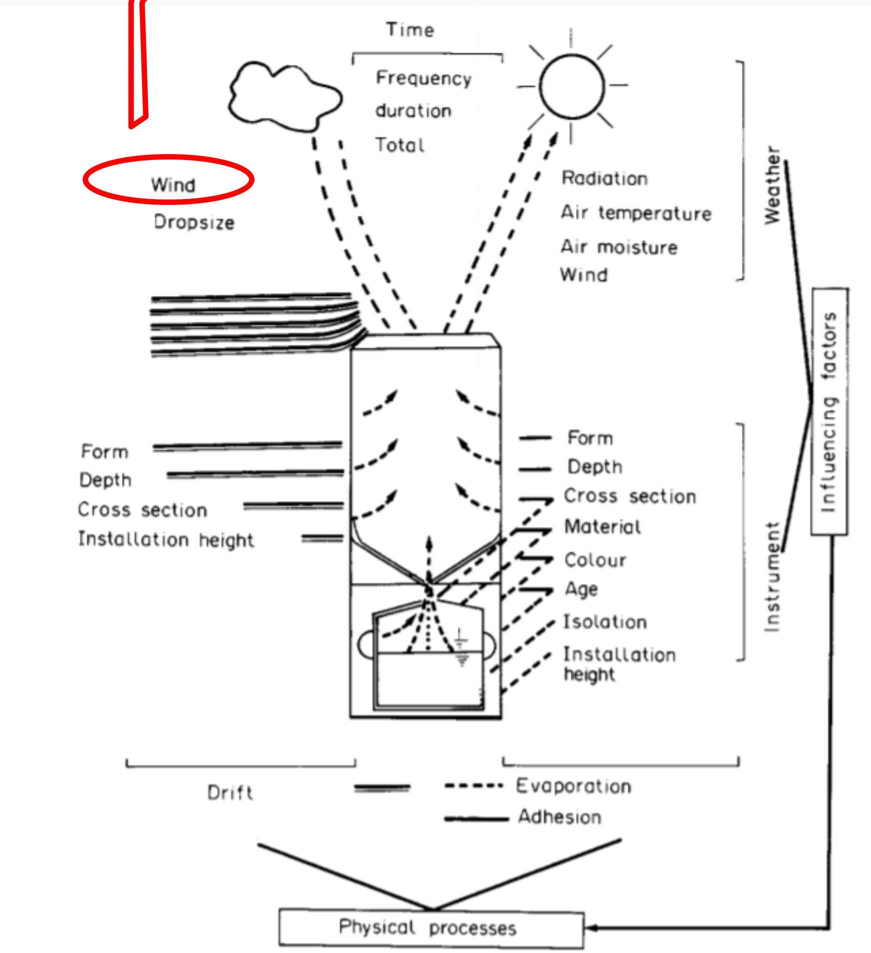
   3.2 Statistic of **correction factor** for solid (Cs) and liquid (Cr) precipitation

4. FUTURE RESEARCH WORKS

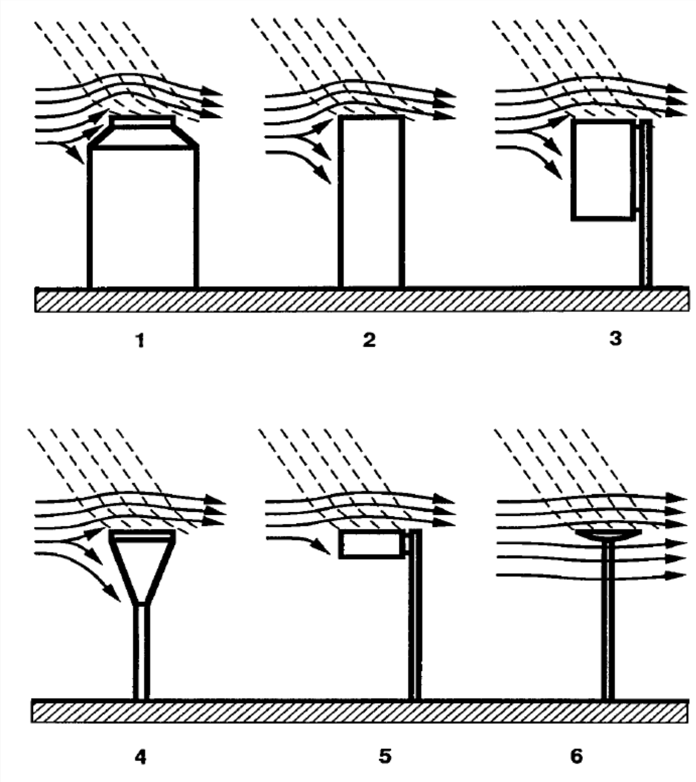
Non constact Cs(x,t) = f(wind intensity); Multi-criteria approaches; Impacts of future CC scenarios & adaptation strategies

# A preliminary global assessment of under-catch of solid precipitation in Canales Basin (Sierra Nevada, Spain)

## 1. INTRODUCTION: Under-catching phenomenon




Relevant physical processes affecting the systematic error of precipitation measurement (Sevruk, 1991)




The phenomenon of wind-induced error of precipitation measurement. Arrows show the streamlines and the dashed lines the trajectories of precipitation particles (Goodison et al., 1998 )

# 1. INTRODUCTION: Under-catching phenomenon

- Brown and Peck (**1962**) studying about **challenges of precipitation measurements.**
- Sevruk (**1982**) described the **methods for correcting systematic errors in precipitation measurements** for operational use.
- WMO Solid Precipitation Intercomparison Committee between 1987 and 1993 (Goodison et al., **1998**): assessed and derived **adjustment functions for solid precipitation measurement** configurations used at that time, which to a large extent are manual observations.
- Rasmussen et al. (**2012**): studying the **relative accuracies of different instrumentation**, gauges and windshield configurations to measure snowfall
- Wolff et al. (**2015**): Determine the wind-induced under-catch of solid precipitation. Qualitative analyses and Bayesian statistics are used to evaluate and objectively choose the model that best describes the data.

Precipitation gauge with Tretyakov shield (Rasmussen et al., 2012)

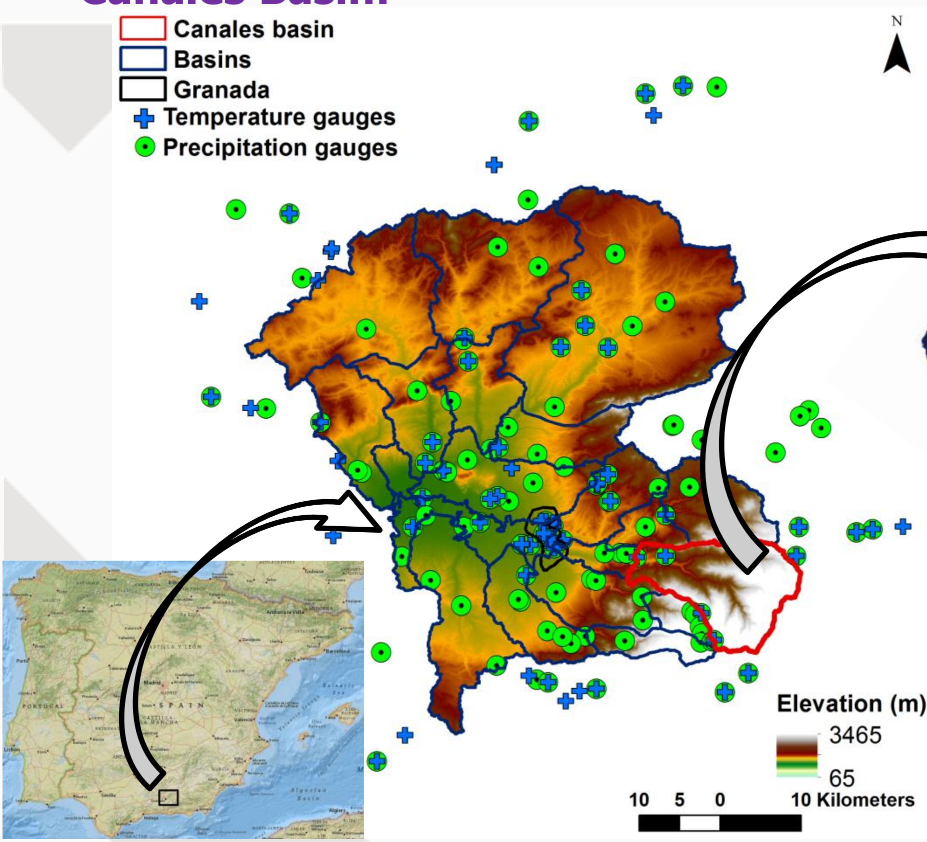
Instituto Geológico y Minero de España

# A preliminary global assessment of under-catch of solid precipitation in Canales Basin (Sierra Nevada, Spain)

## 2. MATERIAL & METHOD

### 2.0. Location of the study area and data (s/t resolution and **LONG periods**)

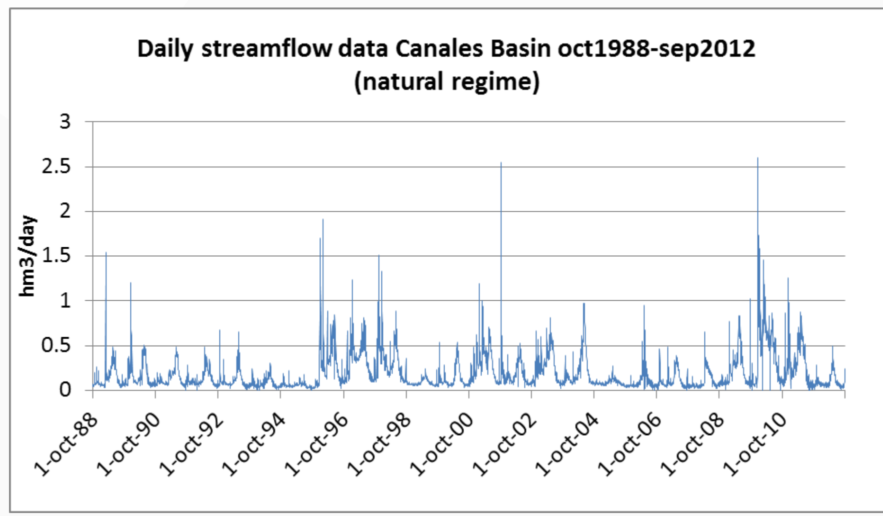
**- Canales Basin:**





● **Streamflow gauge**

176.3 Km²




- **Observations:** Streamflow data (natural regime)
- **Temporal resolution and LONGITUDE OF THE SERIES:** Dialy streamflow (1988-2012)

# A preliminary global assessment of under-catch of solid precipitation in Canales Basin (Sierra Nevada, Spain)

## 2. MATERIAL & METHOD

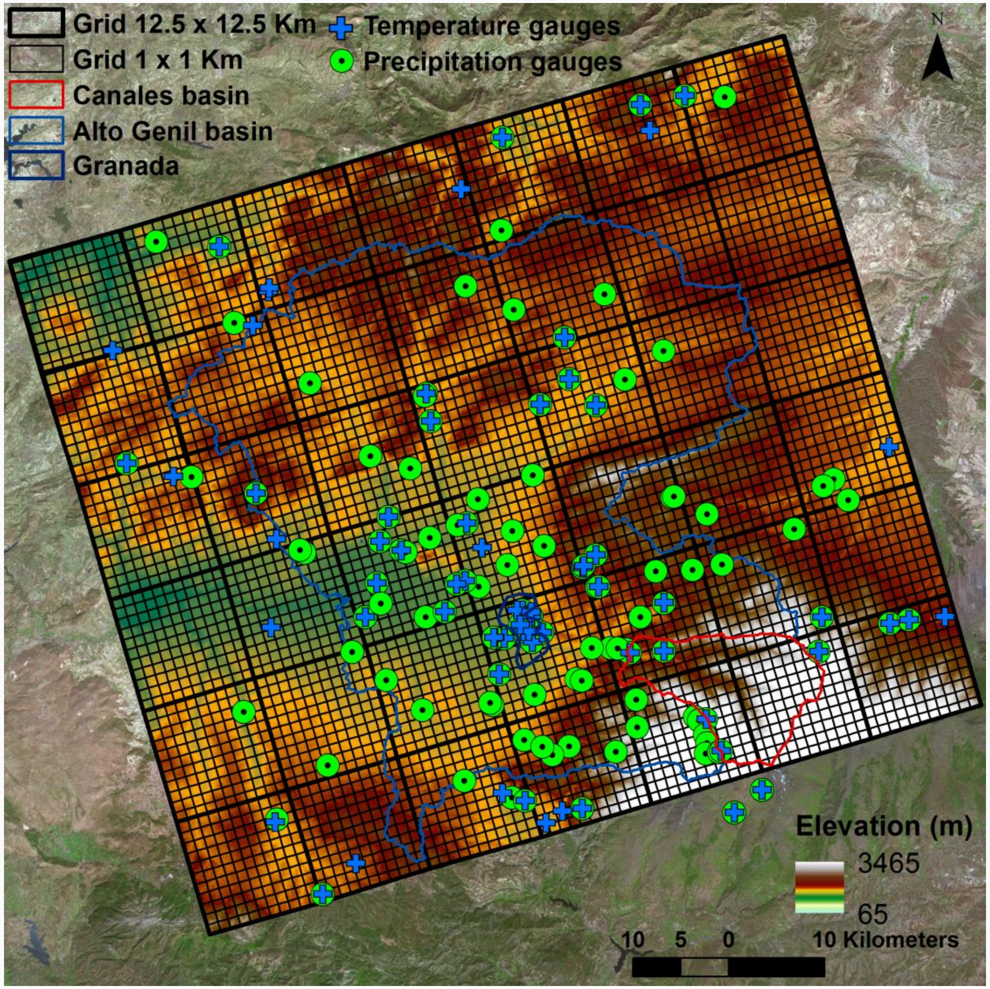
### 2A. Geostatistical estimation of climatic fields (P & T). Hypothesis

**DATA**

- 119 Precipitation gauges
- 72 Temperature gauges
- Temporal resolution: **daily**
- Period: **1980-2014 (34 years)**

Daily **estimation** 1980-2014:

- Spatial resolution: 1km
- Monthly model vs yearly model



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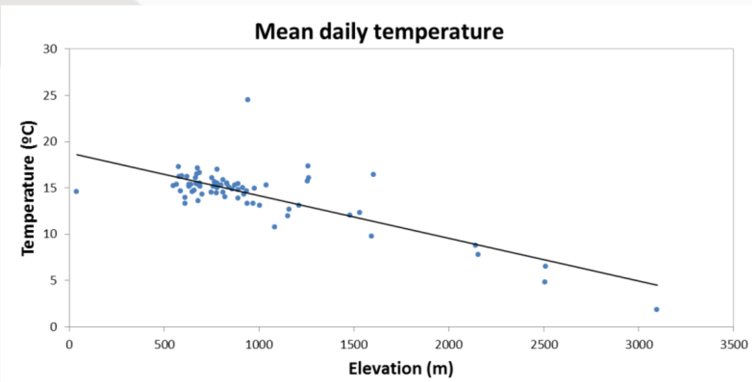
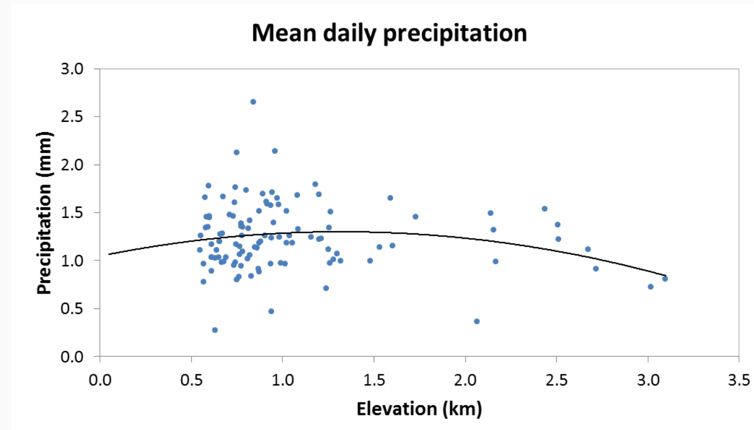
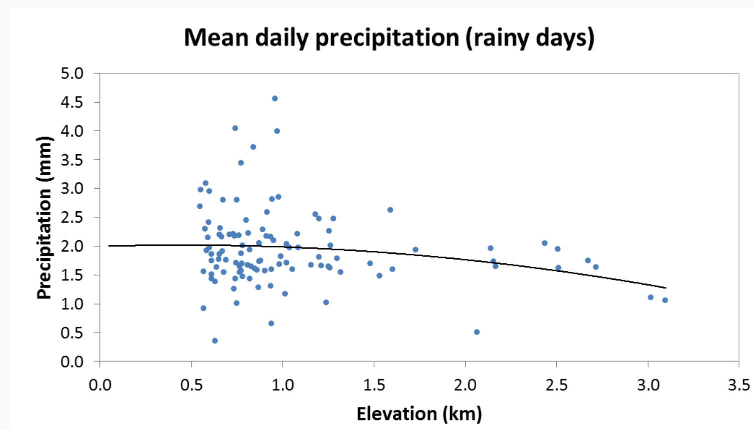



TEMPERATURE: linear relation → KED lineal Tmin + kriging (Tmax-Tmin)

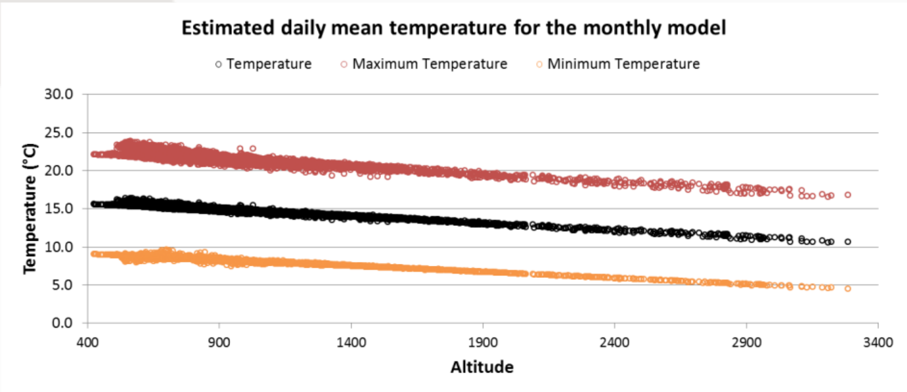
PRECIPITATION: quadratic relationship →

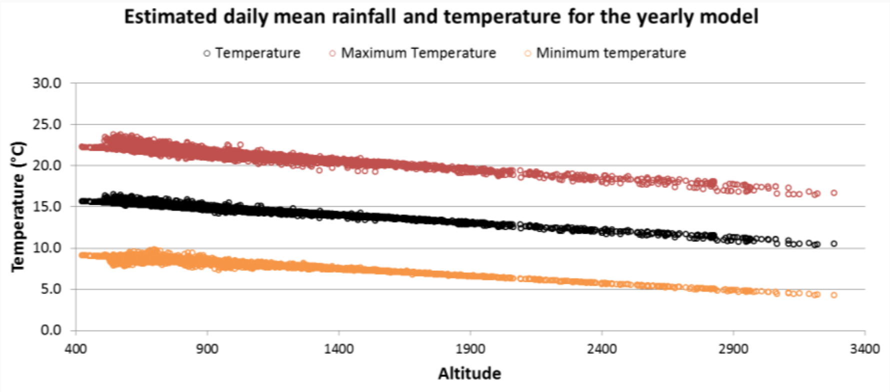
- KED linear
- KED quadratic
- Regression-Kriging using "zeros"
- Regression-Kriging without using "zeros"



# 2. MATERIAL & METHOD

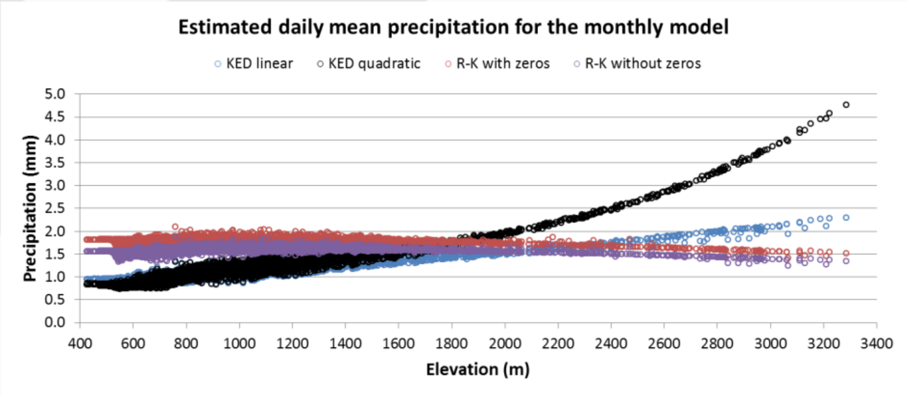
## 2A. Geostatistical estimation of climatic fields (P & T). Hypothesis

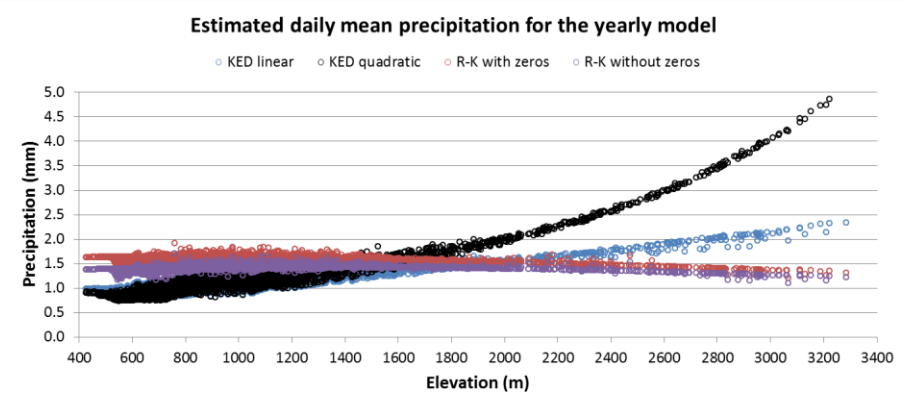



Monthly model

Yearly model

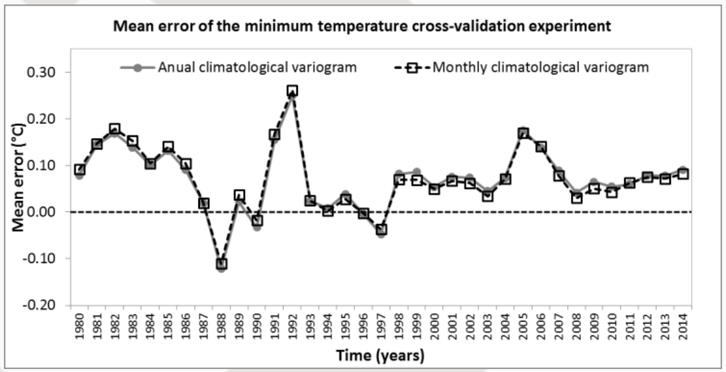


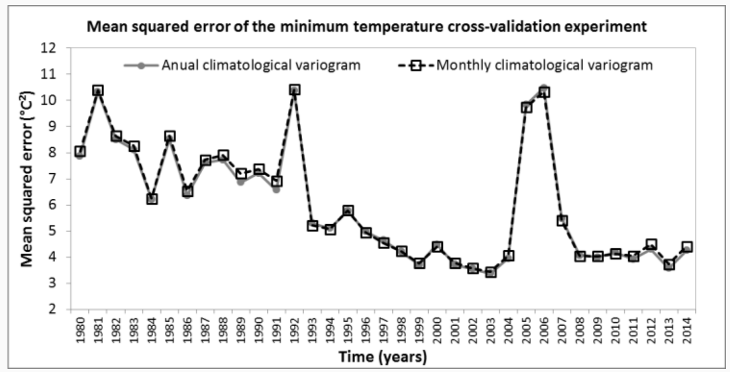



# 2. MATERIAL & METHOD

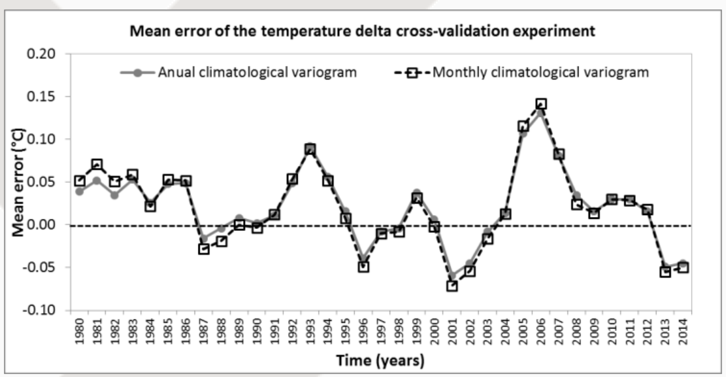
## 2A. Geostatistical estimation of climatic fields (P & T). Hypothesis

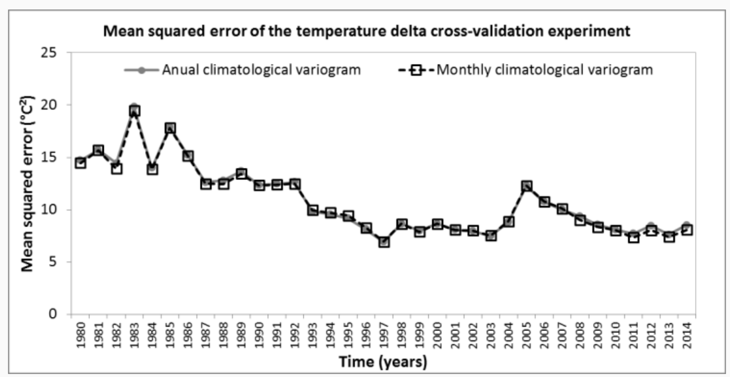
### **CROSS VALIDATION analysis.** TEMPERATURE (KED)




KED Tmin
ME (M.M)=0.072
ME (Y.M)=0.072
MSE (M.M)=6.04
MSE (Y.M)= 5.98



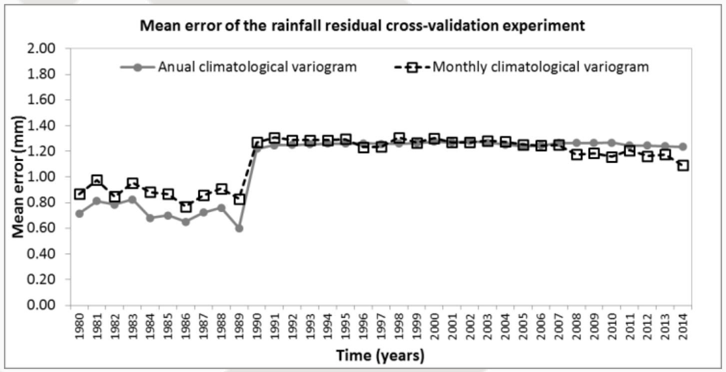



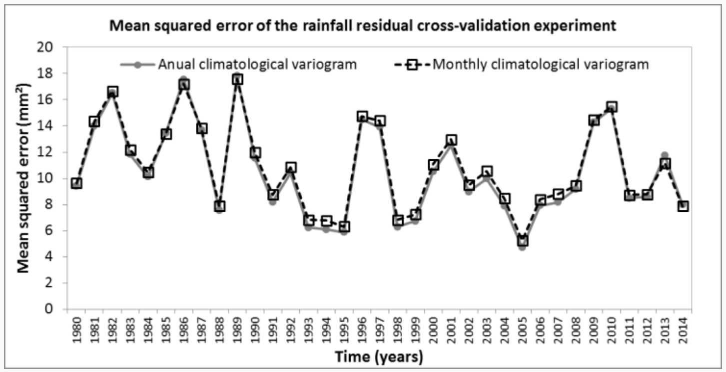

Kriging (Tmax-Tmin)
ME (M.M)=0.020
ME (Y.M)=0.022
MSE (M.M)=10.79
MSE (Y.M)= 10.89

# 2. MATERIAL & METHOD

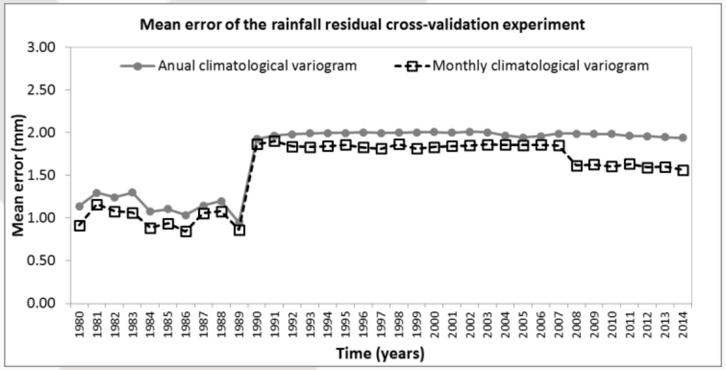
## 2A. Geostatistical estimation of climatic fields (P & T). Hypothesis

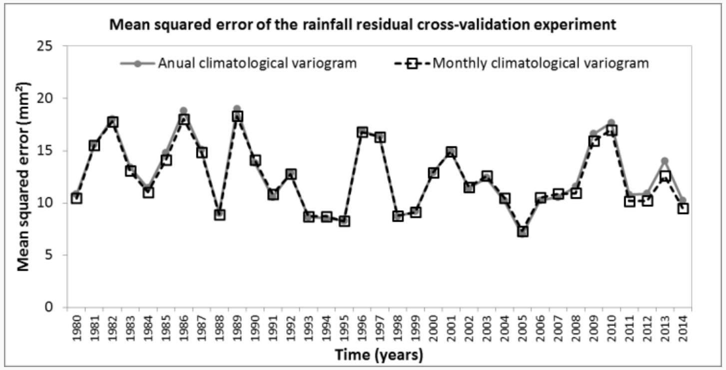
## CROSS VALIDATION PRECIPITATION (R-K)




R-K with zeros
ME (M.M)=1.14
ME (A.M)=1.10
MSE (M.M)=10.5
MSE (A.M)=10.8




R-K without zeros
ME (M.M)=1.56
ME (A.M)=1.74
MSE (M.M)=12.4
MSE (A.M)=12.6

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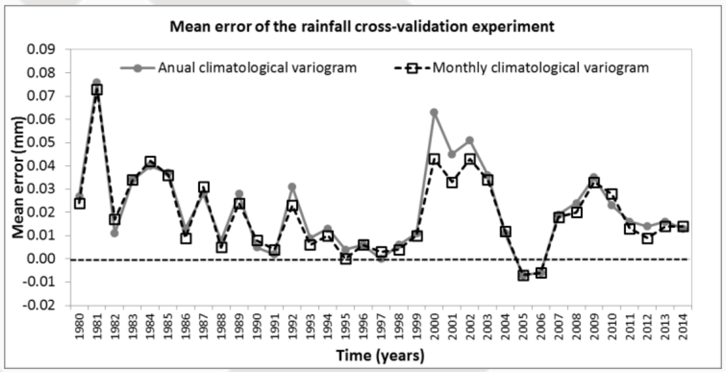
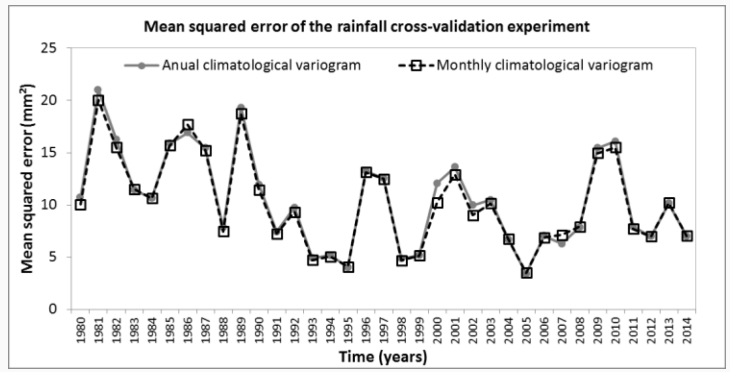
## 2. MATERIAL & METHOD

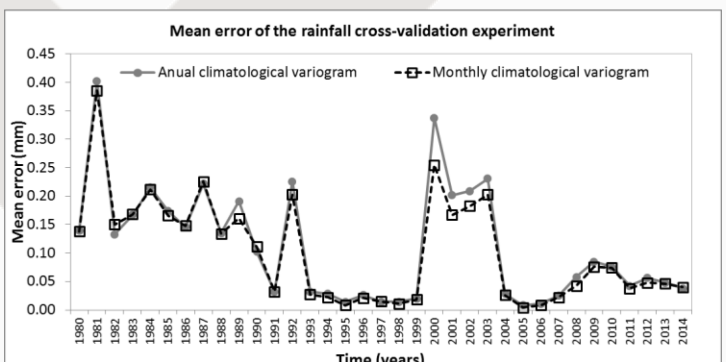
### 2A. Geostatistical estimation of climatic fields (P & T). Hypothesis

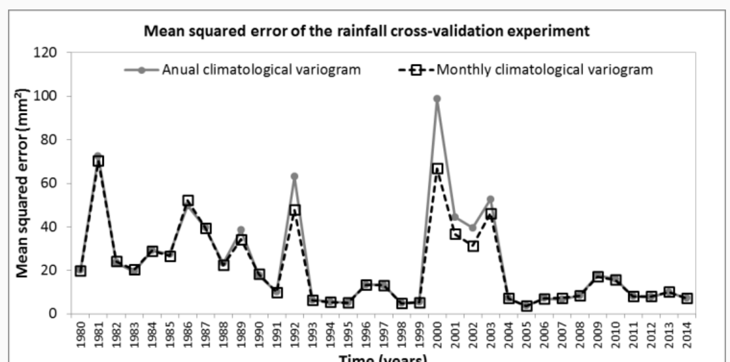
### CROSS VALIDATION PRECIPITATION (KED)




KED linear
ME (M.M)=0.019
ME (Y.M)=0.021
MSE (M.M)=10.19
MSE (Y.M)=10.44




KED quadratic
ME (M.M)=0.103
ME (Y.M)=0.111
MSE (M.M)=21.39
MSE (Y.M)=23.52

# A preliminary global assessment of under-catch of solid precipitation in Canales Basin (Sierra Nevada, Spain)

## 2. MATERIAL & METHOD

2B. Calibration of conceptual hydrological balance model. Sensitivity analysis:

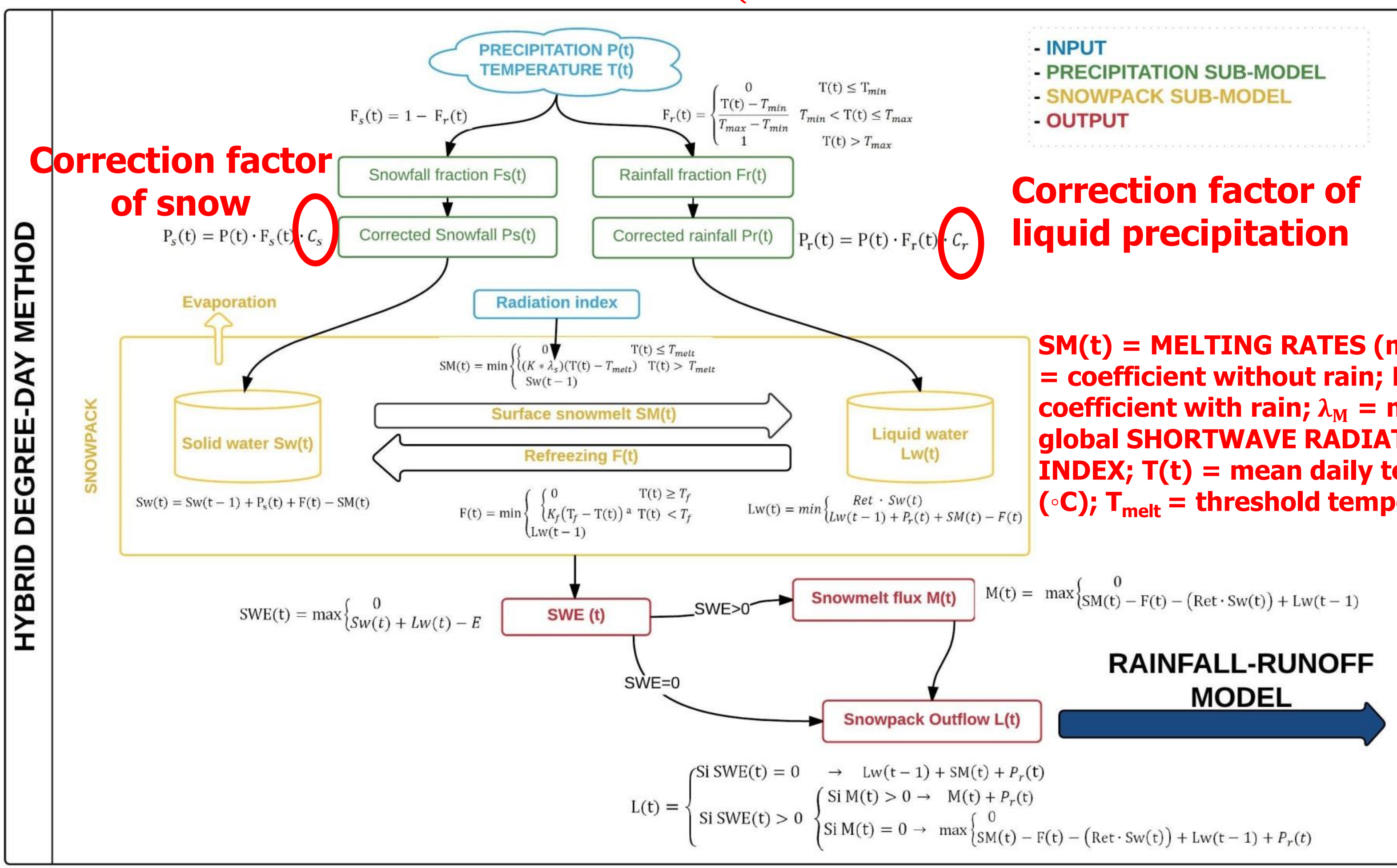
**Distributed** (1x1 kms) **snow approach** (Modified from Irannezhad et al., 2015 & Orozco, 2014)

**Snowmelt approximation = Hybrid degree day method**

$$\mathrm{SM(t)} = \begin{cases} (K_{1,2} \cdot \lambda_M) \cdot (T(t) - T_{melt}) & \text{if } T(t) \geq T_{melt} \\ 0 & \text{if } T(t) < T_{melt} \end{cases}$$

**Correction factor of snow**

**Correction factor of liquid precipitation**

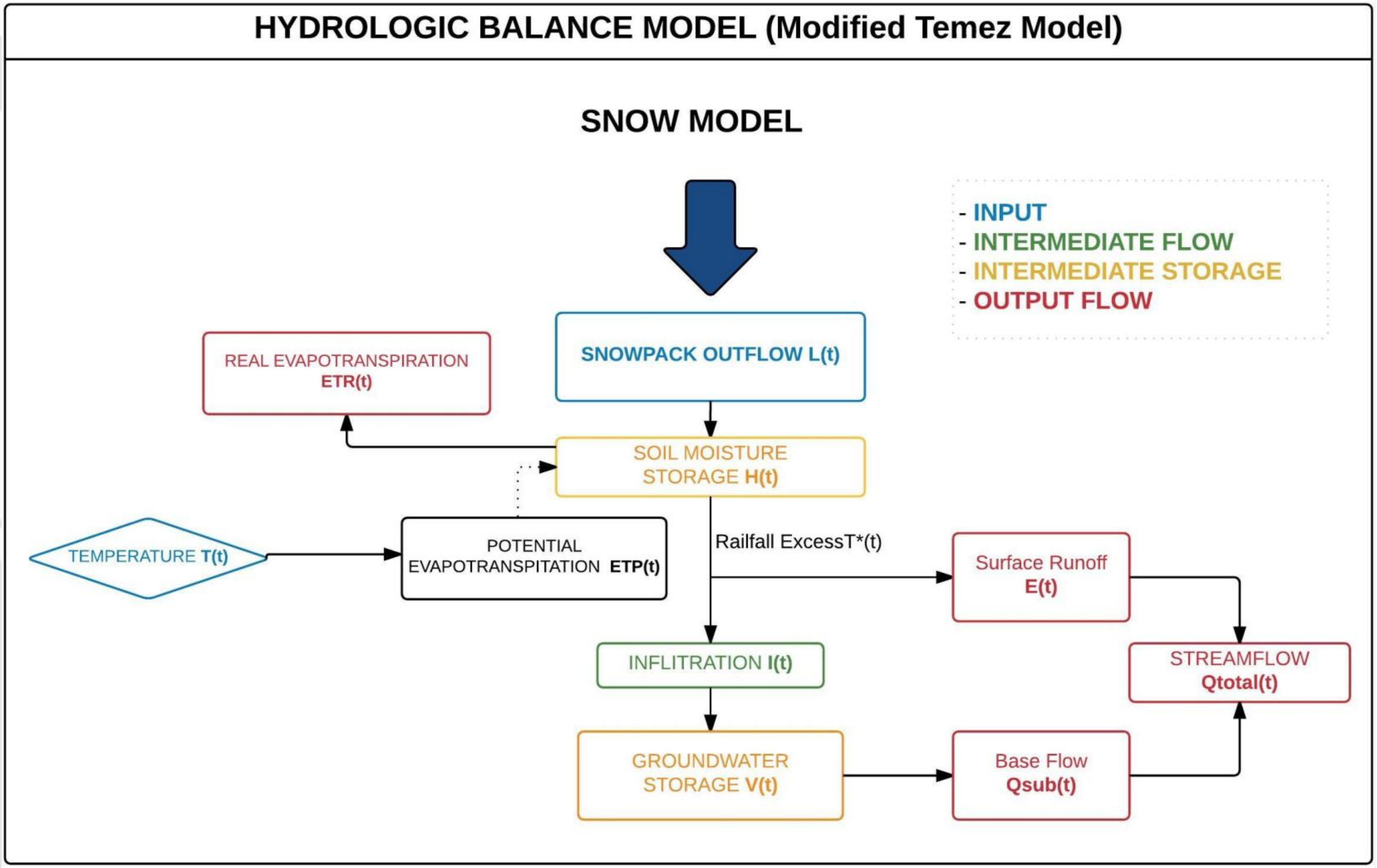



**SM(t) = MELTING RATES (mm/day); $K_1$ = coefficient without rain; $K_2$ = coefficient with rain; $\lambda_M$ = monthly global SHORTWAVE RADIATION INDEX; T(t) = mean daily temperature (◦C); $T_{melt}$ = threshold temperature (◦C)**

## 2. MATERIAL & METHOD

2B. Calibration of conceptual hydrological balance model. Sensitivity analysis:

**Lumped hydrological balance model** (Témez et al., 1977)



2. METHOD & MATERIAL: Automatic Calibration of conceptual hydrological balance model ()

**O.F=** $\min \sum_{t=1}^{n} (Q_{sim}(t) - Q_{obs}(t))^2$

**SELECTION OF THE BEST** OPTIMIZATION **ALGORITHM:**

**Detailed analysis** of **optimization techniques** has been performed. **IMP**:

-High **computational cost** of our optimization problem: Many **data (long time periods) +** 21 parameters to be optimized

-**Noisy Data** $\Rightarrow$ Risk of **local optimal solutions** as the size of dataset increases

## 2. METHOD & MATERIAL: Calibration of conceptual hydrological balance model

**Objectives/concerns: Which is the best algorithm?**

**- How the size of the data**set affects local optima? => **MSE**

- How the **initial solution affects RESULTS** in classic algorithms? => **MSE**

- **Which** algorithmic methodology **is more robust**? =>**SD**(MSE)

- **Which** algorithmic methodology **is more efficient**? => **Computational time**

**Tested Algorithms:**

- LS – Classic Informed Local Search (trust-region-reflective)
- SA – Simulated Annealing
- SA+LS – The solution of SA is used as initial solution for LS
- GA: Genetic Algorithm
- GA+LS – The solution of GA is used as initial solution for LS

**Experimental evaluation:**

- Datasets of length: 2 years, 10 years, 20 years
- Stopping criteria: 3000 evaluations

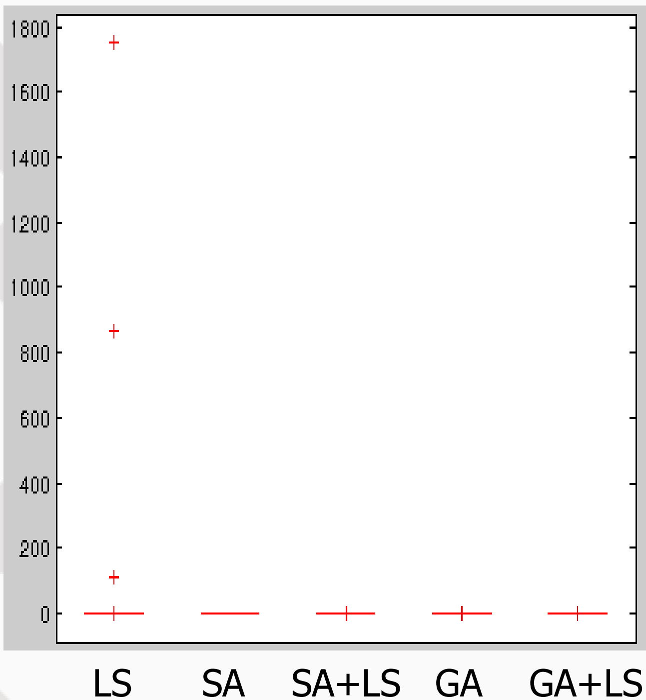
## 3. RESULTS: 3.1 **Best calibration algorithm** = f(longitude of the temporal period)

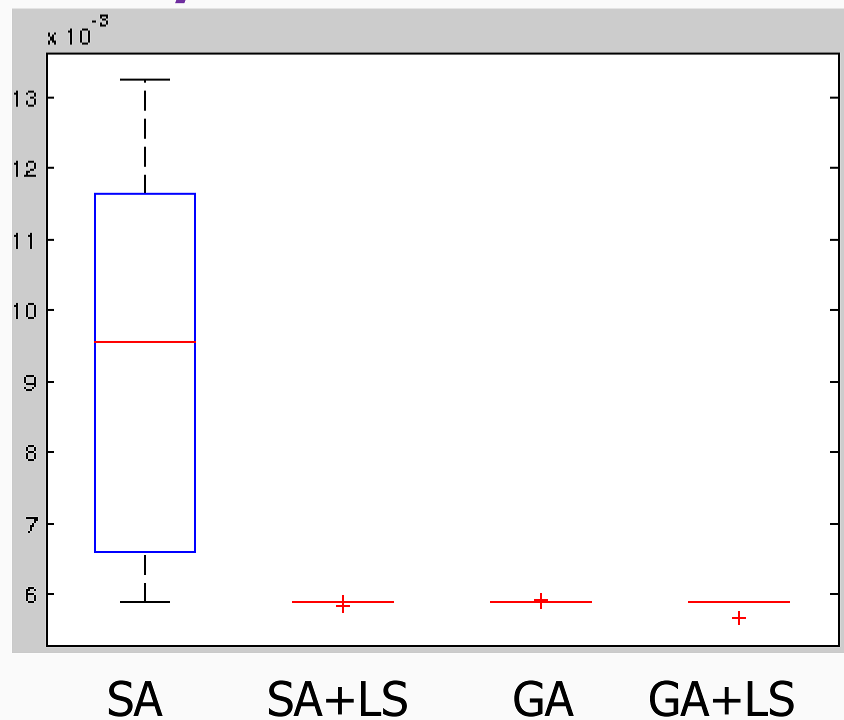
### Size of dataset: last 2 years

| Algorithm | Mean MSE | Median MSE | Best MSE | Worst MSE | S.d. | Average Time per running (s.) | Total time (s.) |
|---|---|---|---|---|---|---|---|
| LS (local search) | 21,66521 | 0,005883 | 0,005555 | 1752,077 | 173,6847 | 23,32679 | 2939,176 |
| SA | 0,009551 | 0,009276 | 0,005897 | 0,013242 | 0,002523 | 87,48397 | 2624,519 |
| GA | 0,005883 | 0,005883 | 0,005838 | 0,005894 | 0,000009 | 105,6492 | 3169,475 |
| SALS | 0,005884 | 0,005885 | 0,005883 | 0,005913 | 0,000005 | 97,49557 | 2924,867 |
| GA+LS | 0,005883 | 0,005876 | 0,005667 | 0,005883 | 0,000039 | 111,1892 | 3335,677 |

## 3. RESULTS: 3.1 **BEST CALIBRATION ALGORITHM** = f(longitude of temporal period)

### Size of dataset: last 2 years



# A preliminary global assessment of under-catch of solid precipitation in Canales Basin (Sierra Nevada, Spain)

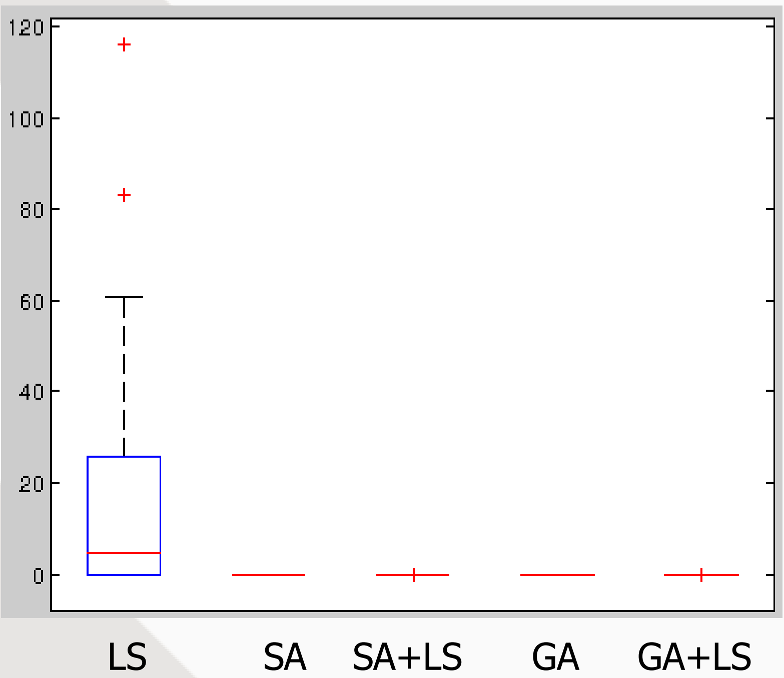
## 3. RESULTS: 3.1 **BEST CALIBRATION ALGORITHM** = f(longitude of temporal period)

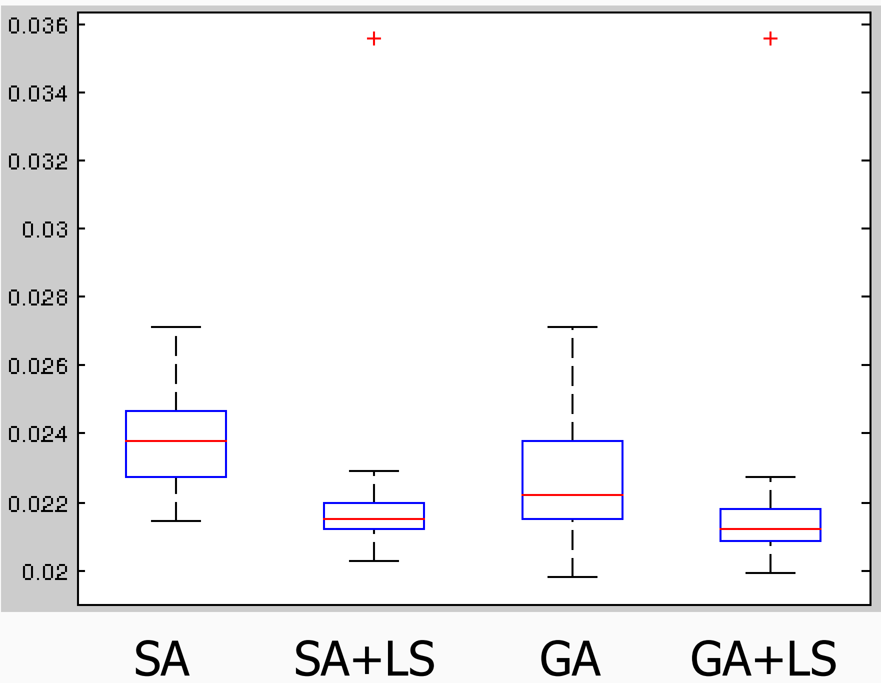
### Size of dataset: last 10 years

| Algorithm | Mean MSE | Median MSE | Best MSE | Worst MSE | S.d. | Average Time per running (s.) | Total time (s.) |
|---|---|---|---|---|---|---|---|
| LS (local search) | 19,29736 | 4,537579 | 0,021985 | 116,0356 | 32,22263 | 477,3874 | 18618,11 |
| SA | 0,023787 | 0,023804 | 0,021474 | 0,027144 | 0,001375 | 567,2712 | 17018,14 |
| GA | 0,021516 | 0,022019 | 0,020297 | 0,035567 | 0,002635 | 647,34 | 19420,2 |
| SALS | 0,022234 | 0,022631 | 0,019804 | 0,027144 | 0,001646 | 615,799 | 18473,97 |
| GA+LS | 0,021218 | 0,021764 | 0,019952 | 0,035567 | 0,002689 | 714,357 | 21430,71 |

## 3. RESULTS: 3.1 **BEST CALIBRATION ALGORITHM** = f(longitude of temporal period)

### Size of dataset: last 10 years



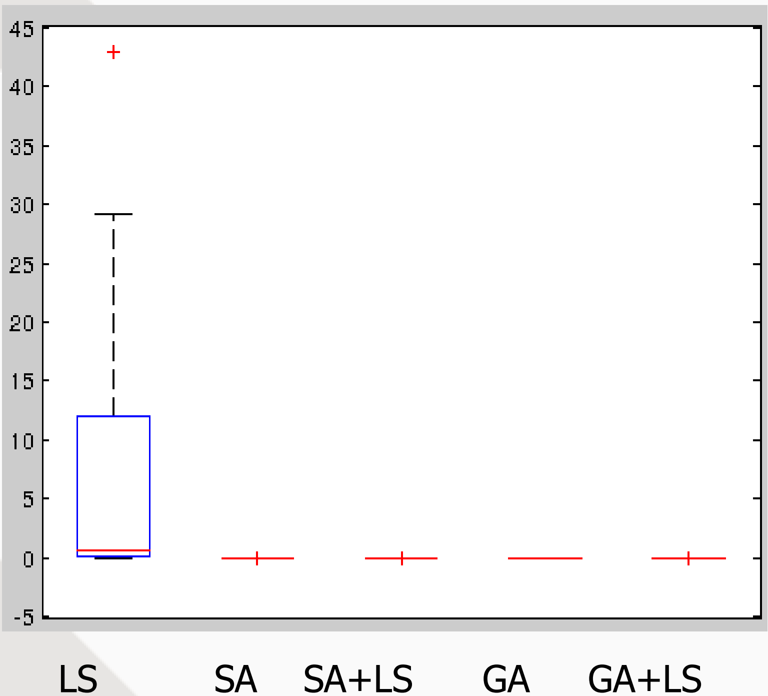
## 3. RESULTS: 3.1 **BEST CALIBRATION ALGORITHM** = f(longitude of temporal period)

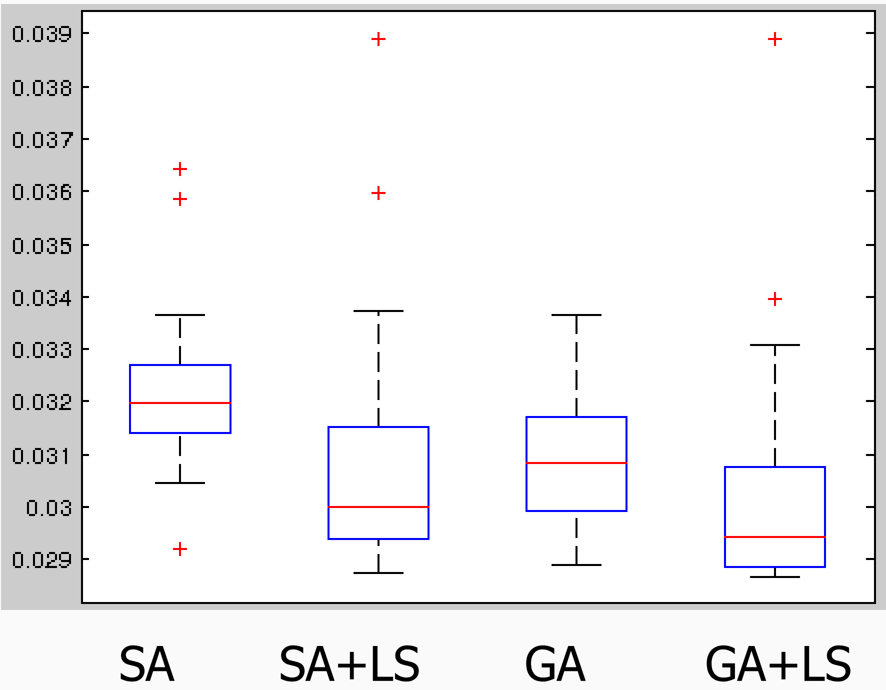
### Size of dataset: last 20 years

| Algorithm | Mean MSE | Median MSE | Best MSE | Worst MSE | S.d. | Average Time per running (s.) | Total time (s.) |
|---|---|---|---|---|---|---|---|
| LS (local search) | 7,437584 | 0,68985 | 0,029464 | 42,93597 | 11,04093 | 1146,329 | 33243,55 |
| SA | 0,03197 | 0,032112 | 0,029189 | 0,036413 | 0,001525 | 1013,463 | 30403,89 |
| GA | 0,030008 | 0,03074 | 0,028742 | 0,038906 | 0,002256 | 1355,369 | 40661,08 |
| SALS | 0,030823 | 0,030888 | 0,028886 | 0,033639 | 0,001242 | 1111,314 | 33339,42 |
| GA+LS | 0,029438 | 0,030174 | 0,028656 | 0,038906 | 0,002158 | 1497,698 | 44930,95 |

3. RESULTS: 3.1 **BEST CALIBRATION ALGORITHM** = f(longitude of temporal period)

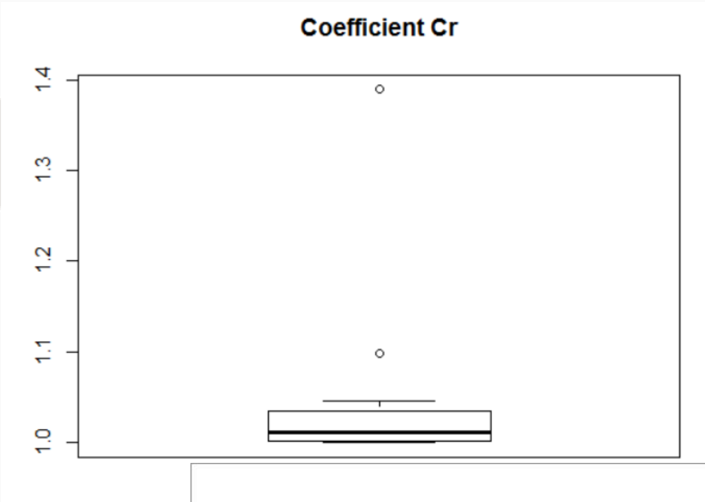
**Size of dataset: last 20 years**

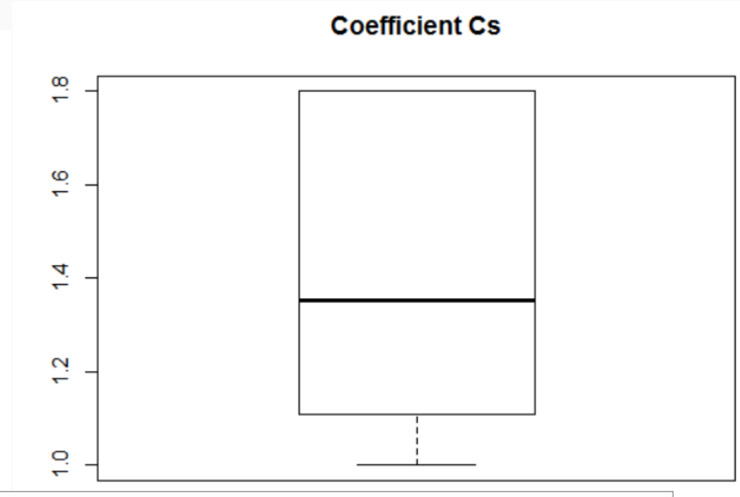


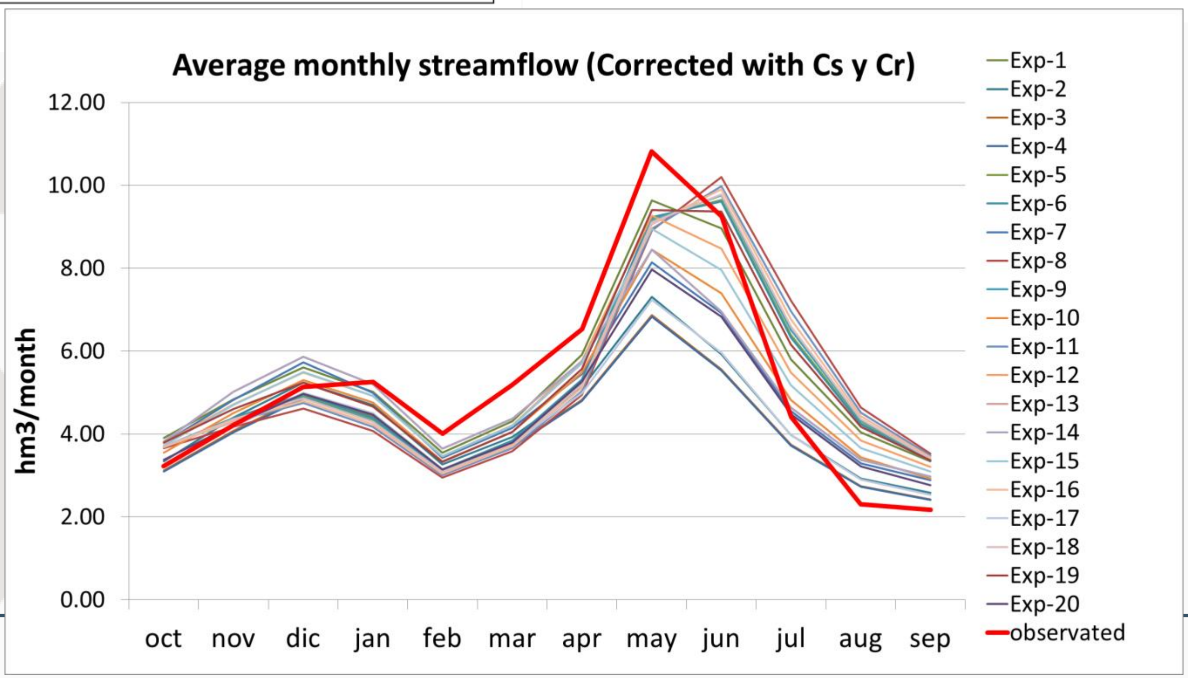




**- GA+LS provided best results in all cases.**
**- Limitation: The computational time is greater, although it is the most robust algorithm.**

## 3. RESULTS: 3.2 Statistic of **correction factor** for solid (Cs) & liquid (Cr) precipitation



# 4. FUTURE RESEARCH WORKS.

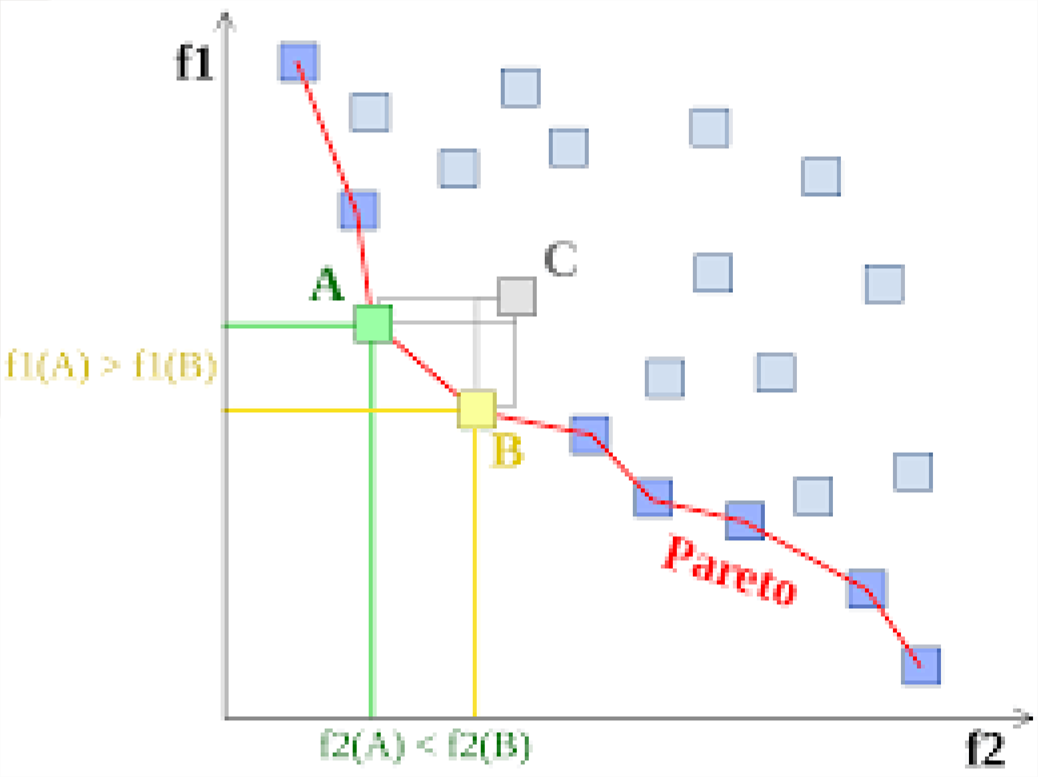
## **4.0 ANALYSES OTHER HYPOTHESIS** IN SNOW MODEL **FORMULATION:**

- **NON-CONSTANT correction of snow factor (Cs) Approaching S/t varibility = f(wind intensity fields);**

- **Other SNOW MODEL APPROACHES**

4. FUTURE RESEARCH WORKS. 4.1 **Multi-criteria calibration approaches. LONG SERIES: Q & SCA** (satellite information + cellular automata simulation where satellite information is not available)

- **Multicriteria approximation: Min{Q, SCA}**



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## 4. FUTURE RESEARCH: **Impacts** of future **CC scenarios** & assessment of **adaptation strategies** (classical & Hydro-ecomic **management models at basin scale**)

- **BG: Systhematic method** to asses **Problems & Solutions** ⇒ indices=f(Management model) (Pulido-V, et al., 2011)

114 D. Pulido-Velazquez et al. / Journal of Hydrology 405 (2011) 110–122

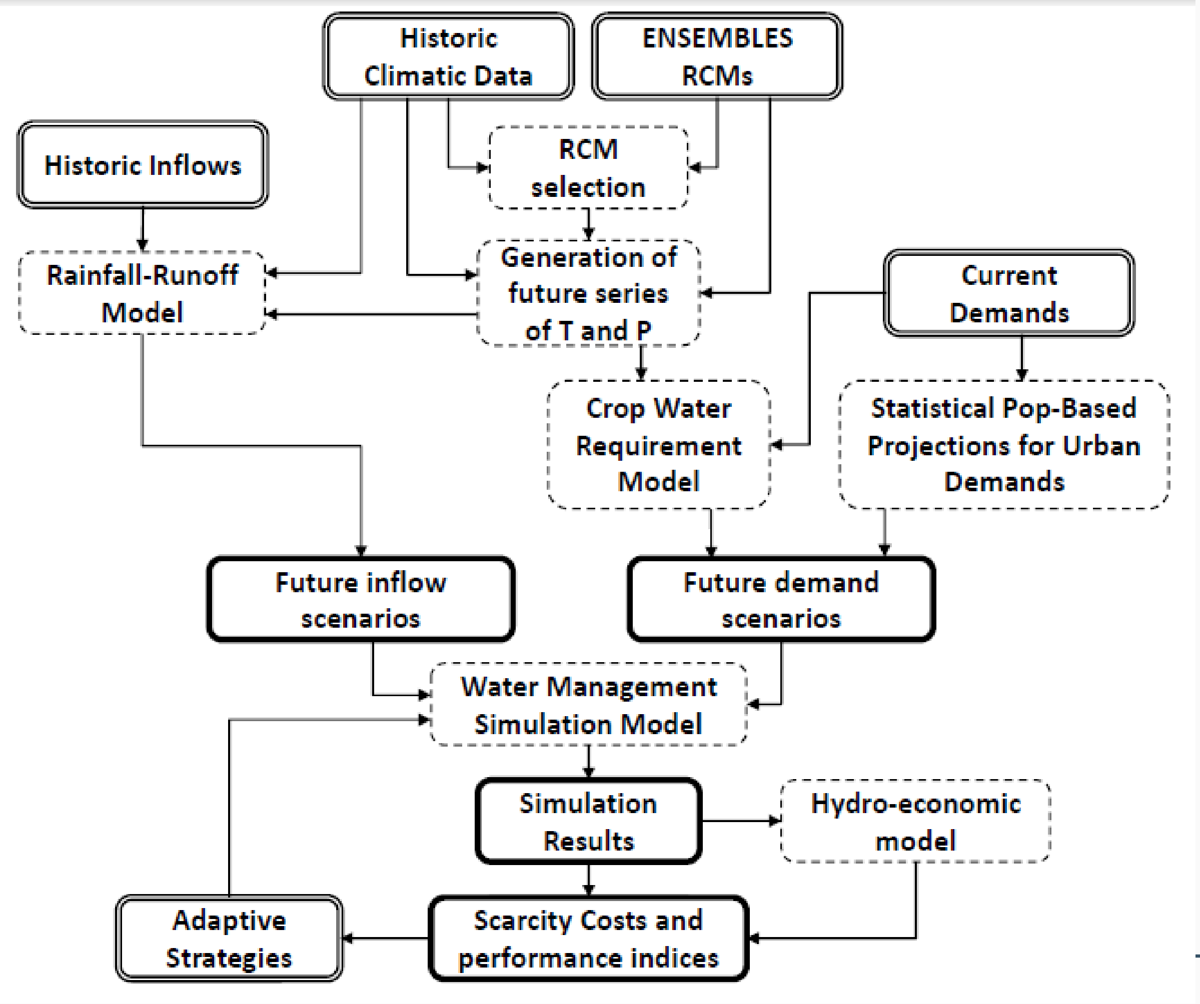
**Table 1**
Problems and solutions based on the values of the indices.

| | Withdrawal use ($I_w$) | Withdrawal ($I_u$) | Demand reliability ($I_r$) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | High ($I_s^+$) | | Intermediate ($I_s^=$) | | Low ($I_s^-$) | |
| | | | Problems | Solutions | Problems | Solutions | Problems | Solutions |
| *Demand satisfaction ($I_s$)* | | | | | | | | |
| High ($I_s^+$) | High ($I_w^+$) | High ($I_u^+$) | | | $2^=$ | $A^-$ | $2^+$ | $A^-$ |
| | | Low ($I_u^-$) | | | $2^=–4^-$ | $A^-–C^-$ | $2^+–4^-$ | $A^-–C^-$ |
| | Low ($I_w^-$) | High ($I_u^+$) | | | $2^=–3^-$ | $A^-–B^-$ | $2^+–3^-$ | $A^-–B^-$ |
| Intermidiate ($I_s^=$) | High ($I_w^+$) | Low ($I_u^-$) | $1^=–4^=$ | $A^=–C^=$ | $1^=–2^=–4^=$ | $A^=–C^=$ | $1^=–2^+–4^=$ | $A^=–C^=$ |
| | Low ($I_w^-$) | High ($I_u^+$) | $1^=–3^=$ | $A^=–B^=$ | $1^=–2^=–3^=$ | $A^=–B^=$ | $1^=–2^+–3^=$ | $A^=–B^=$ |
| Low ($I_s^-$) | High ($I_w^+$) | Low ($I_u^-$) | $1^+–4^+$ | $A^+–C^+$ | $1^+–2^=–4^+$ | $A^+–C^+$ | $1^+–2^+–4^+$ | $A^+–C^+$ |
| | Low ($I_w^-$) | High ($I_u^+$) | $1^+–3^+$ | $A^+–B^+$ | $1^+–2^=–3^+$ | $A^+–B^+$ | $1^+–2^+–3^+$ | $A^+–B^+$ |
| | | Low ($I_u^-$) | $1^+–3^+–4^+$ | $A^+–B^+–C^+$ | $1^+–2^=–3^+–4^+$ | $A^+–B^+–C^+$ | $1^+–2^+–3^+–4^+$ | $A^+–B^+–C^+$ |

+ High = Intermediate – Low
Problem:
1. Vulnerable: water scarcity may produce significant damages.
2. Unreliable: low intensity droughts may lead to water scarcity.
3. Excess of demand with respect to withdrawal (pumping + natural inflows-depletions produced by pumping).
4. Reduced use of withdrawal.
Solution:
A. Demand management.
B. Complementary resources are needed (additional pumping, water transfer, water reuse, etc.).
C. Increase regulation of the system withdrawal (surface structural works, artificial recharge, water reuse, etc.).

## 4. FUTURE RESEARCH: **Impacts** of future **CC scenarios** & assessment of **adaptation strategies** (classical & Hydro-ecomic **management models at basin scale**)

**Hydroeconomic assessment** of **CC impacts** & **adaptation** strategies. **Jucar Basin** (Escriva-Bou, Pulido-V, et al., 2016)



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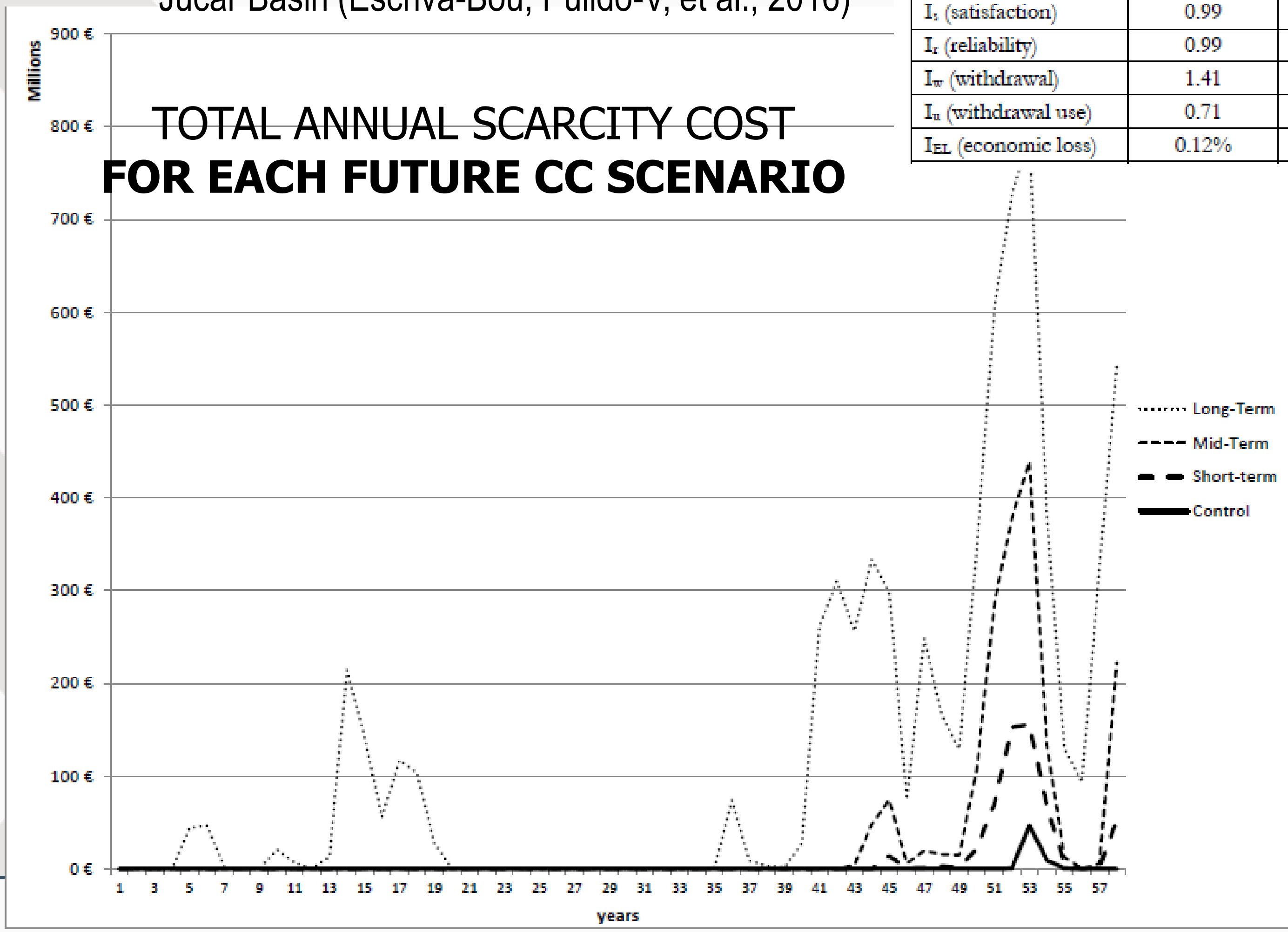
*Indices (also Economic)*

| | Control | Short-Term | Mid-Term | Long-Term |
|---|---|---|---|---|
| $I_s$ (satisfaction) | 0.99 | 0.97 | 0.95 | 0.82 |
| $I_r$ (reliability) | 0.99 | 0.95 | 0.92 | 0.75 |
| $I_w$ (withdrawal) | 1.41 | 1.27 | 1.18 | 0.86 |
| $I_u$ (withdrawal use) | 0.71 | 0.76 | 0.81 | 0.95 |
| $I_{EL}$ (economic loss) | 0.12% | 1.01% | 2.26% | 9.79% |



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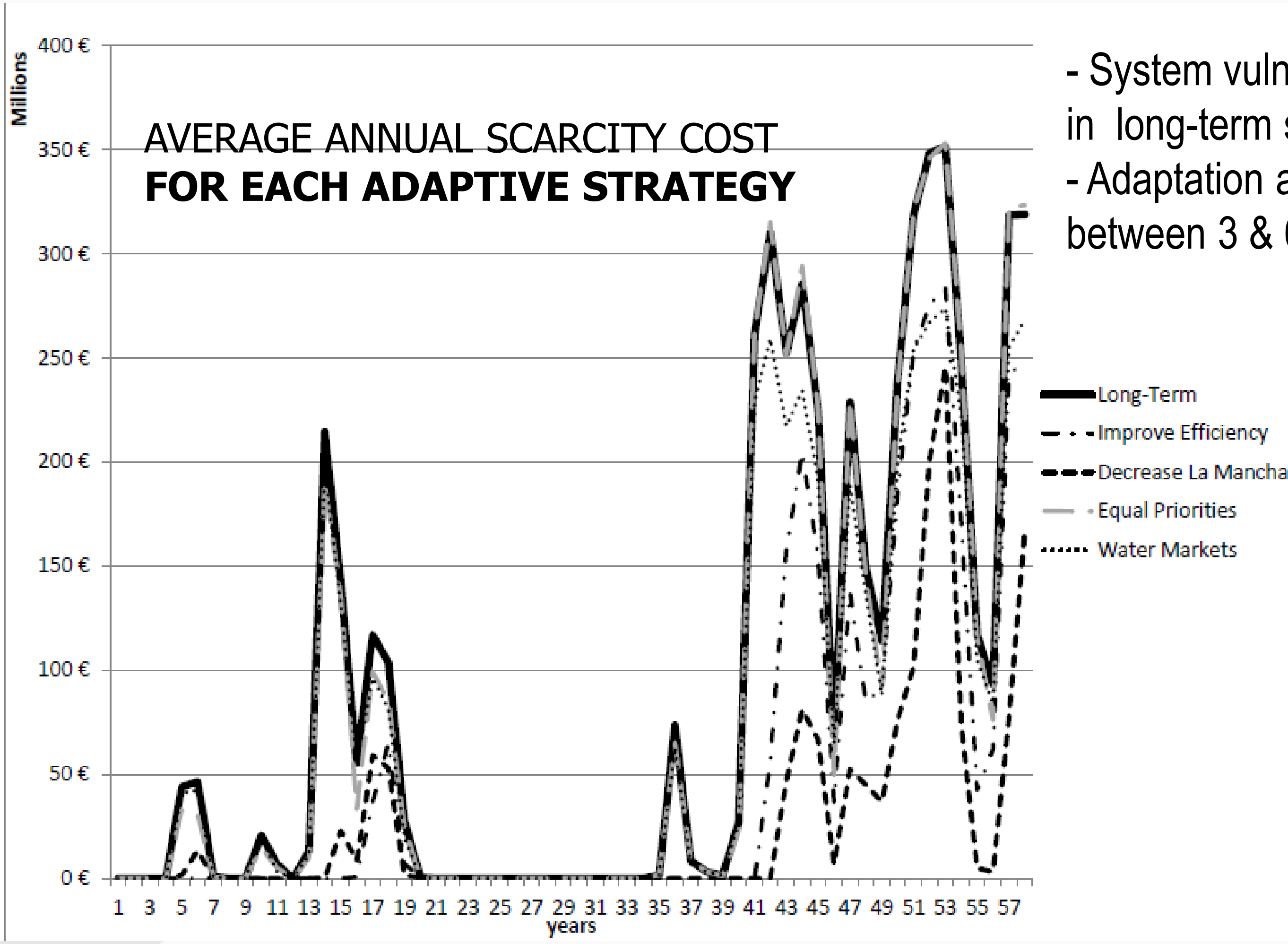


- System vulnerable to GC, especially in long-term scenarios (2071-2100)
- Adaptation actions can save between 3 & 65 M€/year.

# THANK YOU FOR YOUR ATTENTION!!

**David Pulido-Velazquez.** (d.pulido@igme.es)
Spanish Geological Survey, IGME