Assessing surface-groundwater interactions using a coupled geohydrological model for environmental flow estimation

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SMART LAGOON

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INTRODUCTION

General Context

- ✓ Hydrological models are essential for understanding watershed dynamics and the impact of human activities on water resources.
- ✓ In highly anthropized countries, such as Spain, the availability of daily scale data in natural regime becomes a complicated task, so that most of the times it is necessary to apply these models.
- ✓ Daily time-scale models can be complex and deficient in specific contexts (e.g. drier climates) and require higher computational performance. Consequently, there may be a need to study other alternatives.

Previous work

- ✓ We found that a calibration of the SWAT+ model directly at the daily scale gave us an underestimation of the flows, and consequently, of the environmental flows.
- ✓ In contrast, we found that monthly calibration to adjust the monthly volumes of the SWAT+ model followed by a disaggregation based on a daily flow pattern showed better results.

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Research papers

Disaggregated monthly SWAT+ model versus daily SWAT+ model for estimating environmental flows in Peninsular Spain

Gerardo Castellanos-Osorio [a], Adrián López-Ballesteros [a], Julio Pérez-Sánchez [b], Javier Senent-Aparicio [a]

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Highlights

- SWAT+ model and WRAP were coupled to obtain daily streamflow data.
- Disaggregation technique based on flow pattern is recommended.
- Disaggregation of a monthly calibrated model estimates reliable environmental flows.
- SWAT+ model calibrated on a daily scale underestimates environmental flow.
- An alternative for environmental flows estimation in anthropized watersheds is shown.

Objectives

- Coupling of the SWAT+ model with the new gwflow module in order to improve the representation of the watershed and the simulated flow rates.
- Analyse the sensitivity of the parameters, calibrate and validate, at monthly and daily scale, all the scenarios giving more weight/importance to low flows using PEST++ (Sen and iES).
- Evaluation of model performance, application of disaggregation techniques in monthly scenarios, and estimation of environmental flows with the generated daily series.

Scenario 1
SWAT+ Daily Calibration

Scenario 2
SWAT+ Monthly Calibration
Daily disaggregation

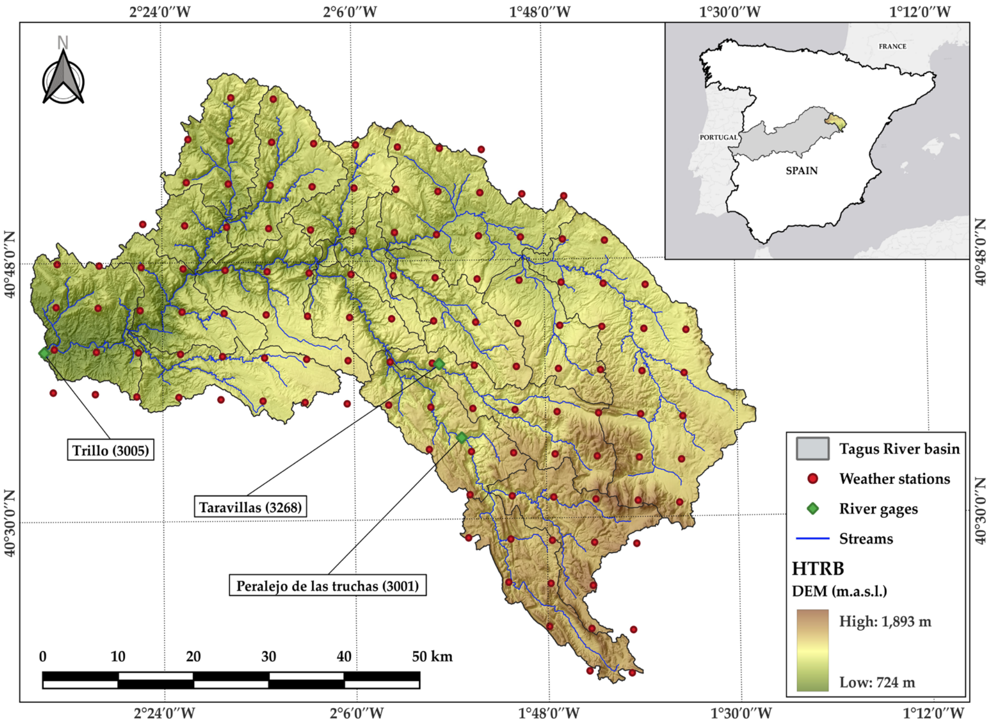
Scenario 3
SWAT+*gwflow*
Daily Calibration

METHODOLOGY

Watershed description

- This area holds significant strategic importance for water resources as it supplies the **Tagus-Segura Water Transfer**. The allocation of water to the Mediterranean region involves national-level political decisions and has been a source of territorial disputes, particularly during drought periods (*Garrote et al., 2007*).

Upper Tagus river basin	
Area	3,252 km^2
Precipitation	627 mm/year
PET	1,174 mm/year
Mean discharge	11.49 m^3/s



SWAT+gwflow. Data collection

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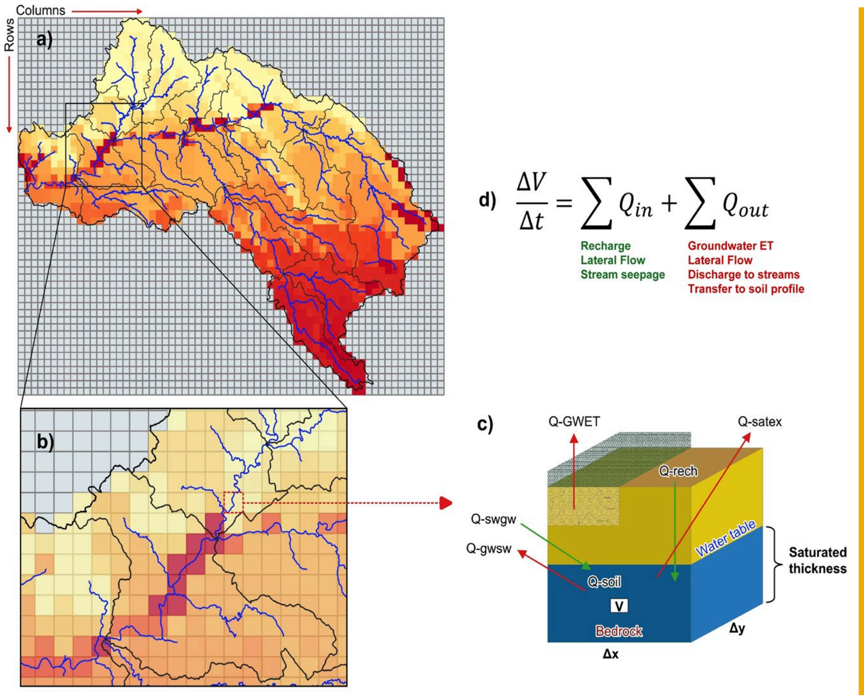
Input	Spatial Resolution	Source
Weather data	5 km x 5 km	Spanish National Meteorological Agency (AEMET)
DEM	25 m x 25 m	National Geographic Institute of Spain (IGN)
Land uses	100 m x 100 m	CORINE Land Cover 2018 (CLC)
Soil	250 m x 250 m	Digital Soil Open Land Map (DSOLMap)
Aquifer thickness	250 m x 250 m	ISRIC World Soil Information
Aquifer permeability	Vector polygon	GLobal HYdrogeology MaPS (GLHYMPS)

- **Observed streamflow data** on monthly and daily scale were extracted from **CEDEX gauging stations no. 3005, 3001 and 3268** located at Upper Tagus Basin for 2000 – 2019 period.



Geographical layout and computation method of SWAT+*gwflow* (*Bailey et al., 2020*)

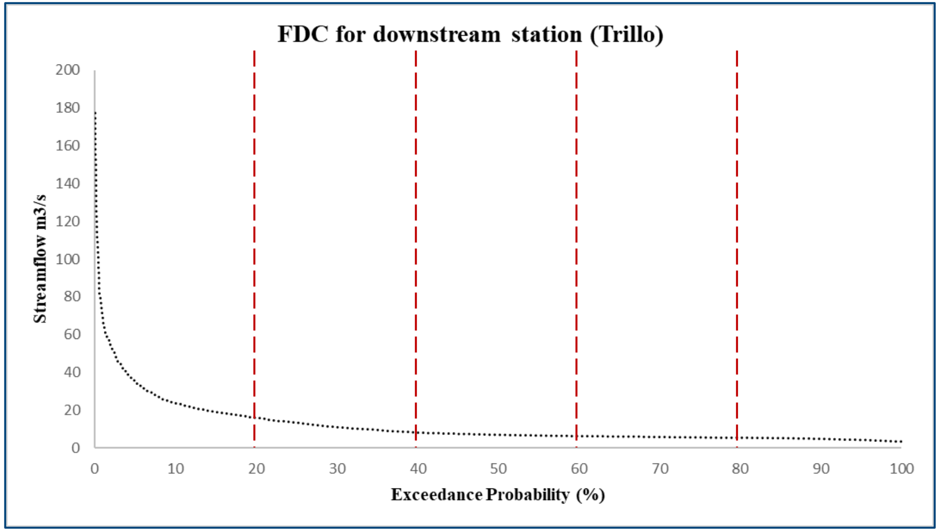
SWAT+gwflow. Model Set-up

- Input data → SWAT → SWAT+ SOIL & WATER ASSESSMENT TOOL
  - Slopes <8%, 8%–30%, and >30%
  - No threshold to HRUs definition
  - Hargreaves PET method

SWAT+*gwflow*
- Grid cell size: 400m
- Initial gwhead: Piezometry

- Sensitivity analysis → PEST++ Sen (Morris GSA, 1991)
- Uncertainty analysis
- Parameter Estimation

PEST++ iES (iterative Ensemble Smoother)



Warm-up | 1995-1999 | Calibration 2000-2009 | 2010-2019 Validation

SWAT+gwflow. Model Set-up

- Input data

- Slopes <8%, 8%–30%, and >30%
- No threshold to HRUs definition
- Hargreaves PET method

(*López-Ballesteros et al., 2024*)

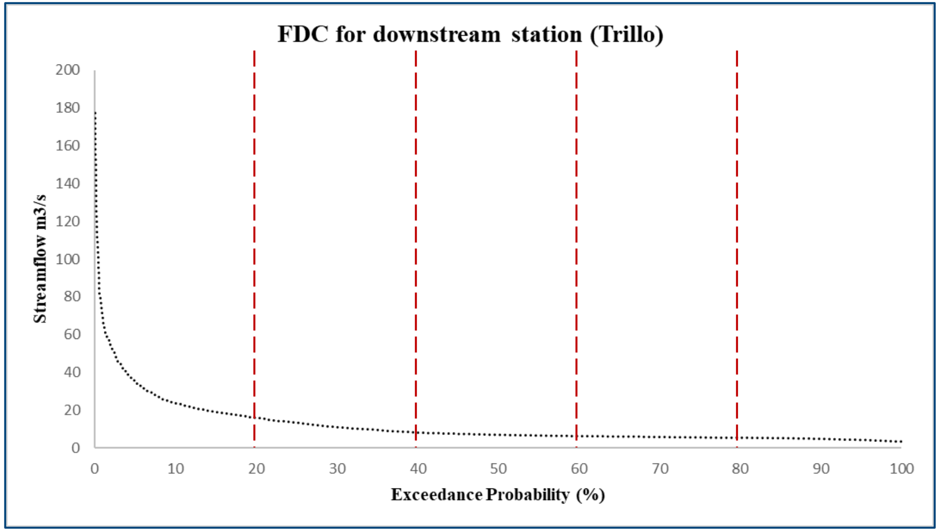
(**Session G1 on Friday**)

SWAT+*gwflow*

- Grid cell size: 400m
- Initial gwhead: Piezometry

- Sensitivity analysis → PEST++ Sen (Morris GSA, 1991)
- Uncertainty analysis
- Parameter Estimation

PEST++ iES (iterative Ensemble Smoother)



Calibration

Warm-up | 1995-1999 | 2000-2009 | 2010-2019 | Validation

RESULTS

Sensitivity Analysis and Parameter Estimation

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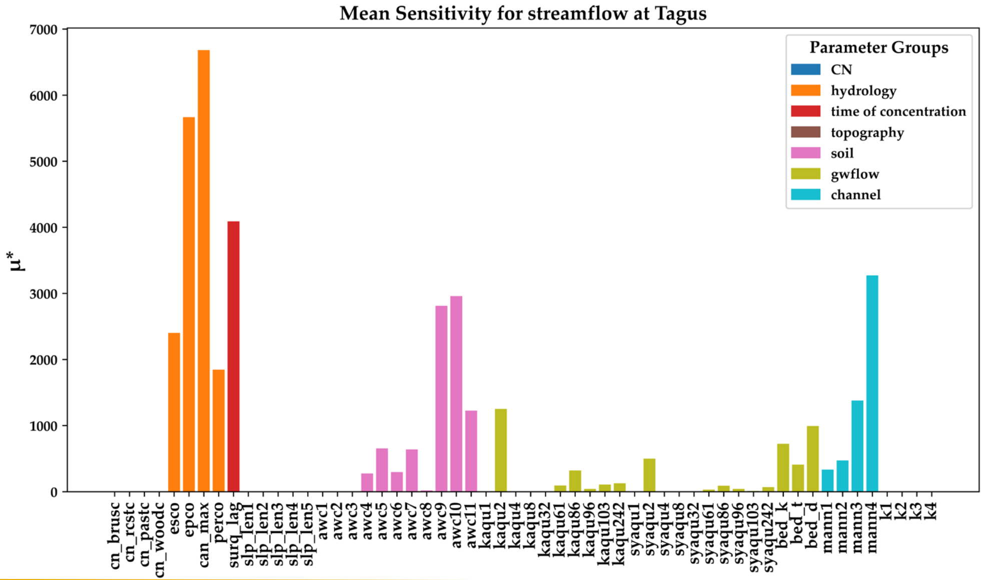

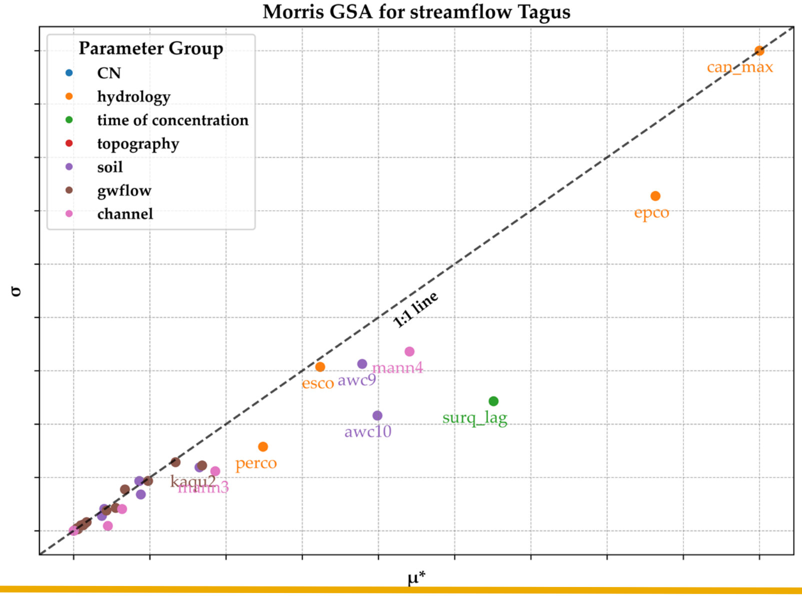

Hydrology	
can_max	11.77
epco	0.02
esco	0.12
perco	0.72

Time of concentration	
surq_lag	2.22 days

Soil	
awc #	0.01 - 1

Groundwater	
Kaqu2	1.3338
bed_d	4.27 m
bed_K	4.10e-5

Channel	
mann4	0.048

SWAT+gwflow monthly calibration

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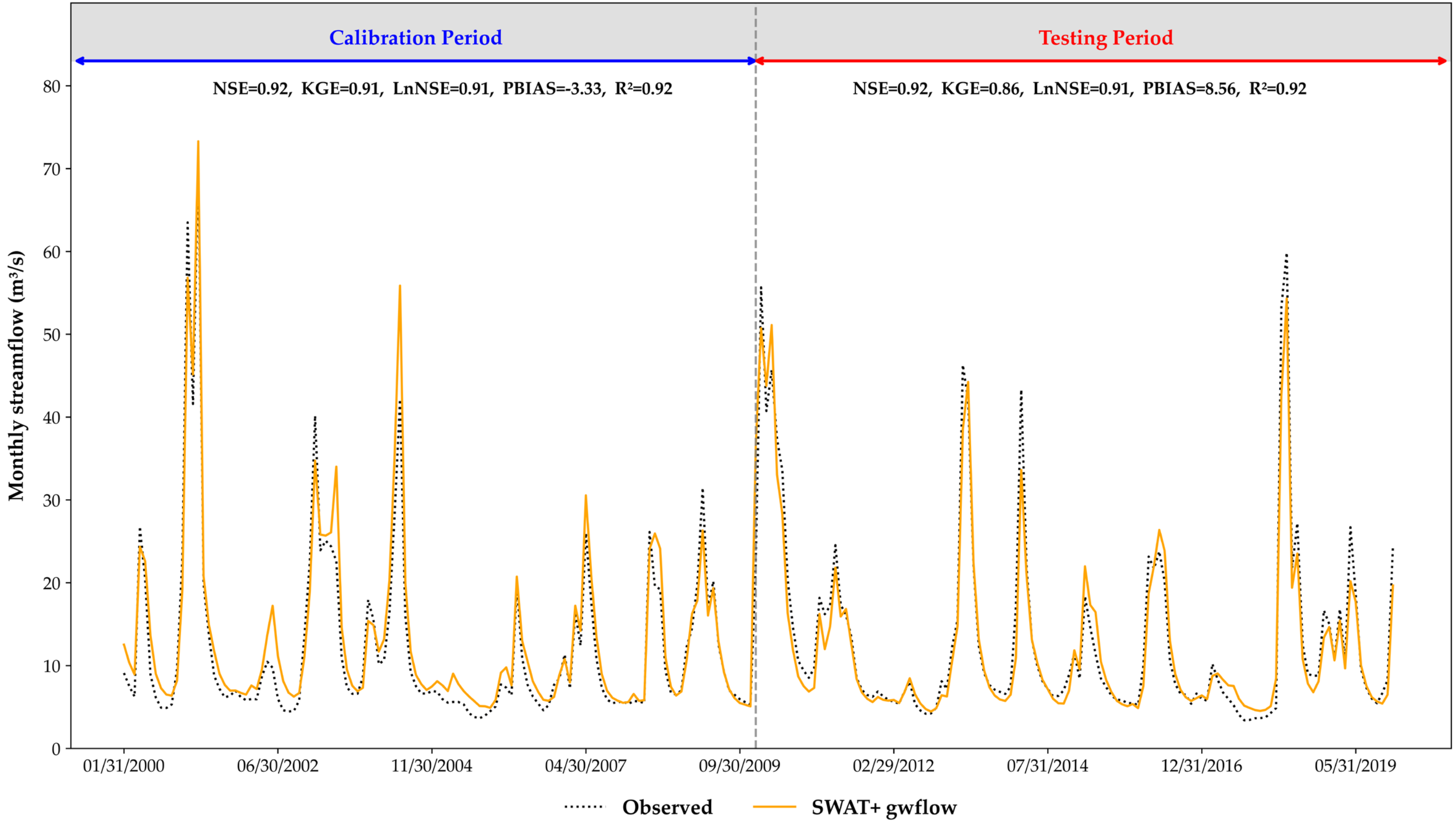
- Downstream station (Trillo)



SWAT+gwflow daily calibration

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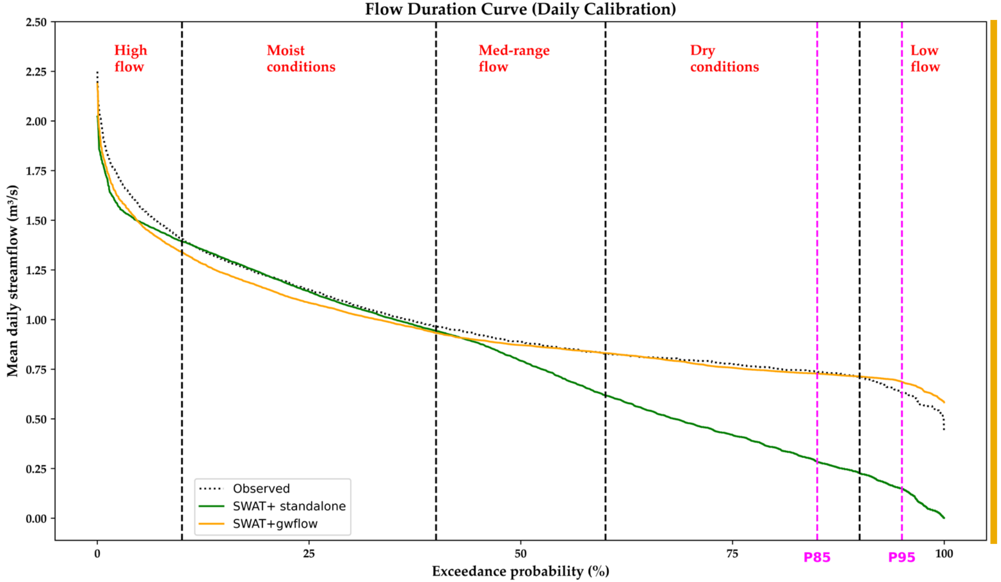
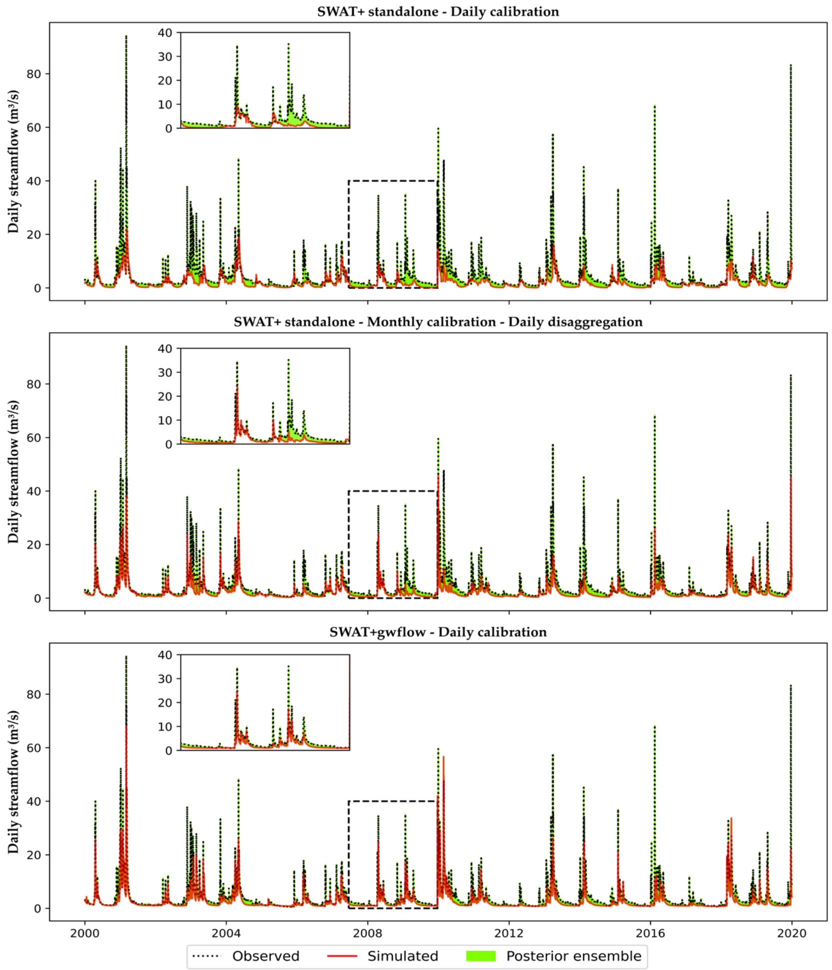
- **Downstream station (Trillo)**





Environmental Flow Estimation

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- **SWAT+ standalone – Daily Calibration**

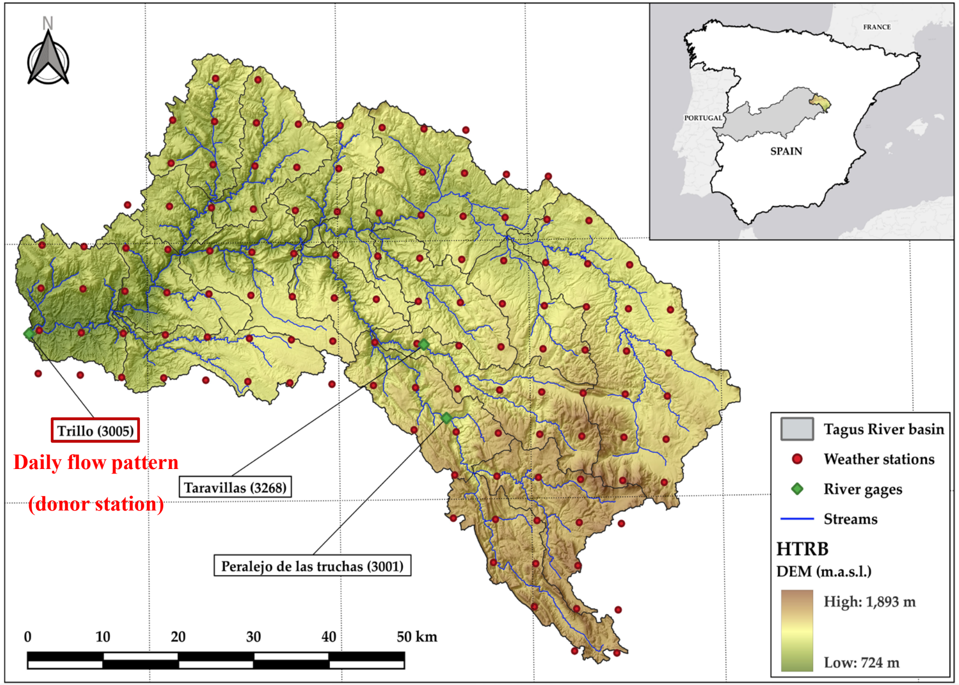
Station	Qb	Q95	Q85	25Qm	21Qm
3005	-60.53%	-69.74%	-65.28%	-67.38%	-67.40%
3001	-77.23%	-84.05%	-81.45%	-80.74%	-80.69%
3268	-69.76%	-62.50%	-61.65%	-66.08%	-66.20%

- **SWAT+ standalone – Monthly Calibration – Daily disaggregation**

Station	Qb	Q95	Q85	25Qm	21Qm
3005	-50.22%	-62.92%	-63.88%	-58.07%	-57.26%
3001	-55.80%	-68.89%	-64.56%	-61.86%	-62.05%
3268	-33.22%	-43.54%	-33.01%	-24.27%	-25.56%

- **SWAT+ *gwflow* – Daily Calibration**

Station	Qb	Q95	Q85	25Qm	21Qm
3005	-8.04%	-13.07%	-20.12%	-14.11%	-13.86%
3001	-12.04%	-9.23%	-7.05%	-19.74%	-8.83%
3268	-1.02%	+14.9%	+2.15%	+2.45%	+2.82%



- We used the disaggregation technique #4 (*replication of a daily flow pattern*) included in the WRAP modeling system (*Wurbs, 2021*).
- The base flow method (Qb) (*Palau and Alcázar, 2012*), based on 100-days moving average, is the most widely used in the hydrological planning in Spain.

CONCLUSIONS

Conclusions

- ✓ Using soil maps with finer ***spatial resolution*** and more detailed ***soil profiles***, such as DSOLMap, in hydrological modelling lead to a better representation of daily hydrological responses.
- ✓ After ***calibration***, only the DSOLMap reached satisfactory daily streamflow predictions with a ***minimal variation range*** of the SWAT+ parameters.
- ✓ For the Anduña watershed, the ***hydrological process estimations*** were aligned between the DSOLMap and the HWSD but not with those of DSWM.

THANKS FOR YOUR ATTENTION