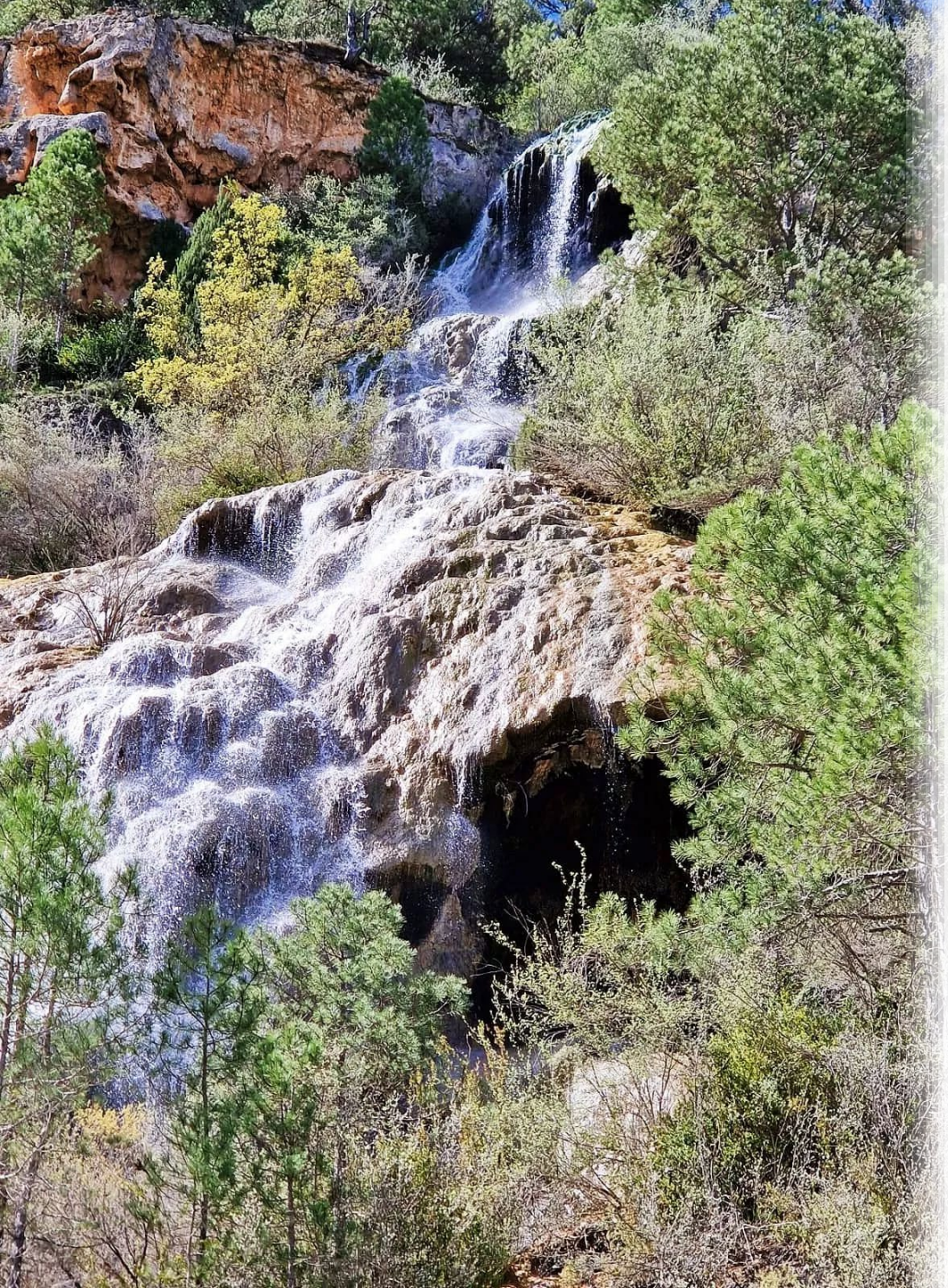

COUPLING GWFLOW TO SWAT+ IN A GEOLOGICALLY HETEROGENEOUS CATCHMENT: PRELIMINARY RESULTS

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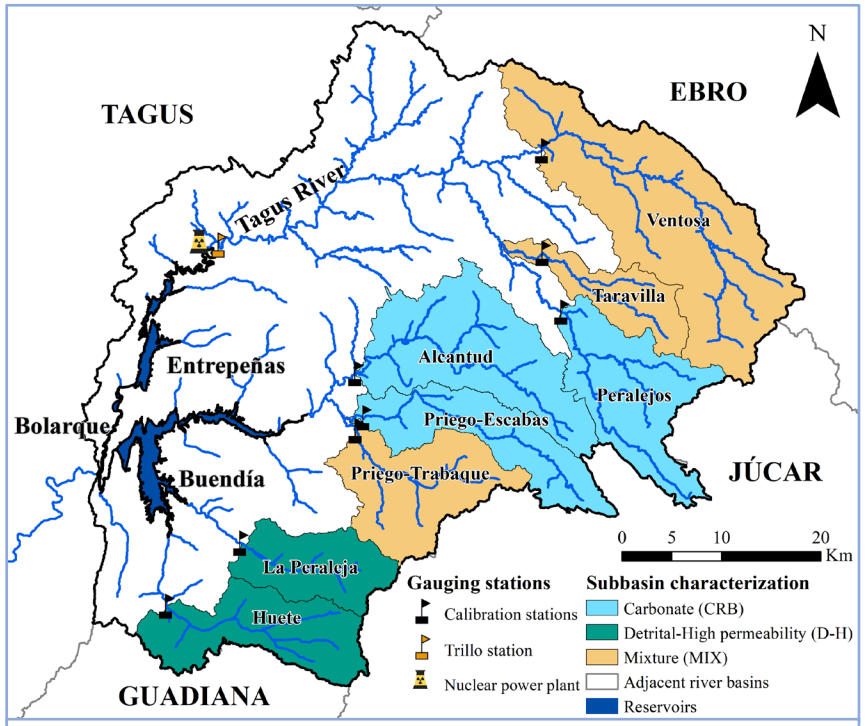
ACMA Agua, Clima y Medio Ambiente

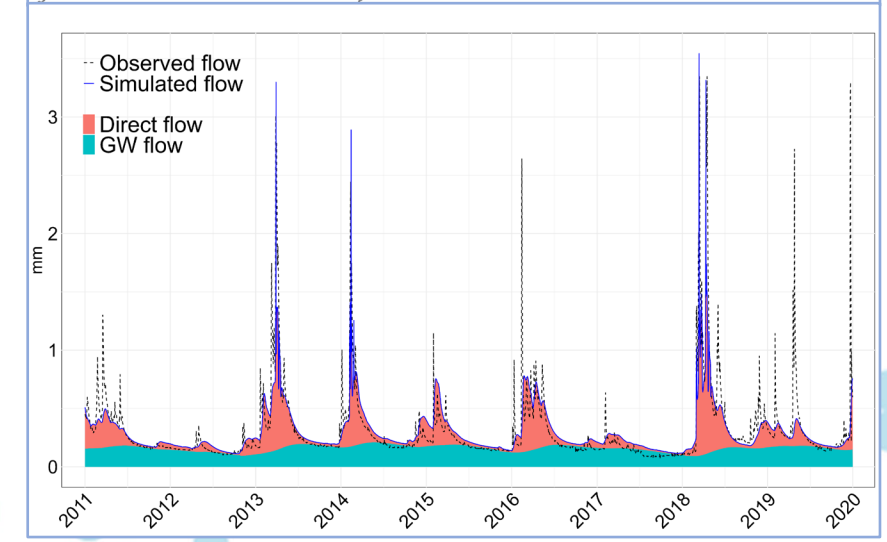
HML – UAH Hydrological Modelling Lab

1. Introduction

Tagus headwaters → Great relevance

- Lower water availability due to climate variability
- Subject to the Tagus-Segura water transfer to southeast Spain (330 hm³ /year).
- A model with a high level of detail has been calibrated in SWAT+ for this area.





2023 SWAT Conference

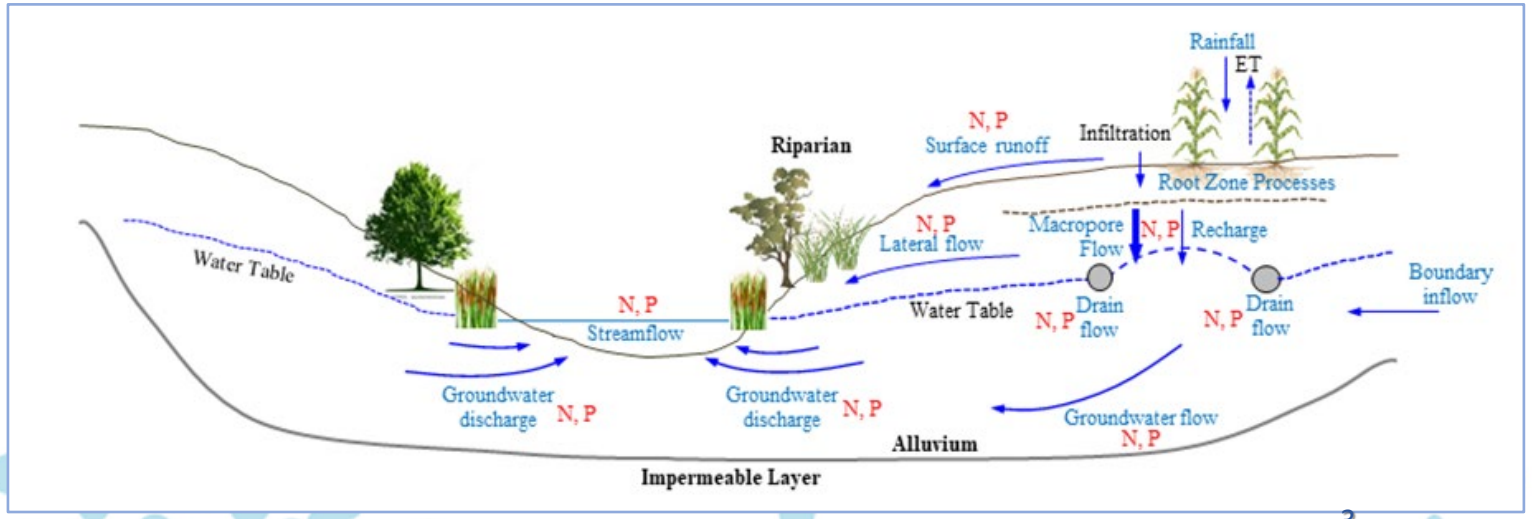
AARHUS UNIVERSITY
DEPARTMENT OF ECOSCIENCE

15:00 - 16:30	**Session C3: Sensitivity Calibration and Uncertainty** Tools Room 104	Moderated by Eugenio Molina-Navarro, University of Alcalá
15:00 - 15:20	**Eugenio Molina-Navarro** Evaluation strategies to identify the best simulation after a zonal calibration process using SWAT+: Application to the Tagus headwaters	

1. Introduction

gwflow module for SWAT+

- Groundwater plays a crucial role in the hydrological processes in the study area
- Integrated with the surface water flow module from SWAT+ for a more detailed representation of the hydrological processes than its original groundwater module.
- Provides advanced capabilities:
  - More variables and parameters that favor hydrogeological representation.
  - Fully distributed at gridcell level
  - Spatial visualization of data results
  - Simulation of piezometric levels



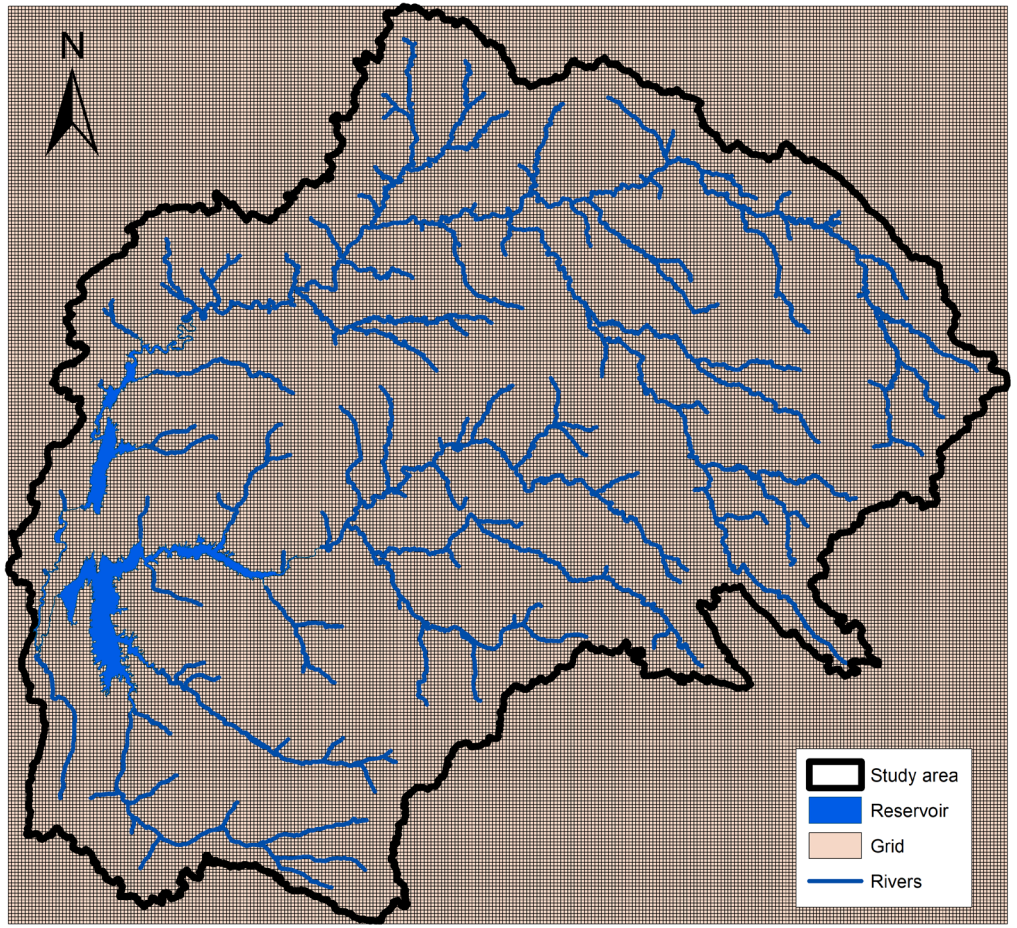
2. Objectives

Simulate the groundwater of the Tagus headwaters

- **To set up a hydrological model with coupled SWAT+ gwflow**
  - Define the aquifers areas in Tagus headwaters basin
  - Generate SWAT+ link files with gwflow module → Solve connecting issues
- **To address a simple sensitivity analysis of the model.**
  - Run default model
  - Evaluate the influence of gwflow parameters on groundwater fluxes and streamflow

1. Model set up

- Grid 400 X 400 m
- GW information shapes
  - Aquifers (*Aquifer Properties*)
  - Cell Information (*grid_thick_dem_K*)
- SWAT+ connection shapes
  - HRUs (*hru_cell_inters*)
  - Channels (*cell_channel_inters*)



1. Model set up

Aquifers

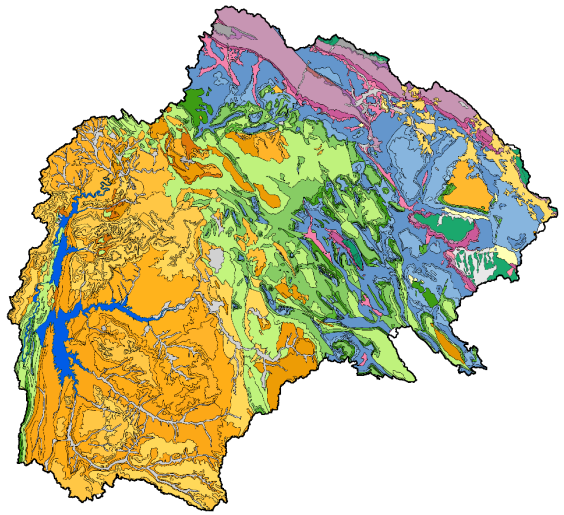
- Singular and varied lithology, from Paleozoic to Quaternary
- Relevant aquifers in the area

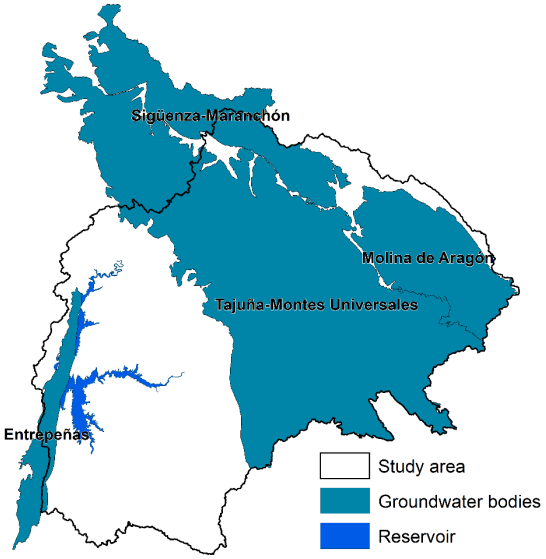
4 WFD groundwater bodies

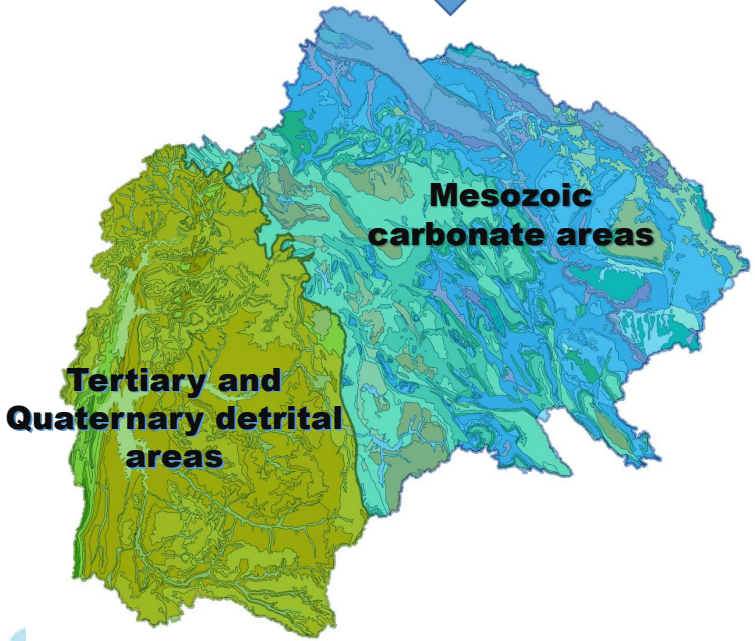
2 aquifer zones defined

CRB and DETR aquifers

Tajuña GWB boundary to separate them







1. Model set up

HRUs shape→ Split + Simplification

PROBLEM 1

Joined HRUs as a result of split in one landuse

HRUS	Area HRU.con	Area GIS	cell_id	poly_area
6, 9, 12	11200.00	13123.30	2461	1881.68
6, 9, 12	11200.00	13123.30	2754	10053.60
6, 9, 12	11200.00	13123.30	2755	1188.02
7, 10, 13	6400.00	7499.03	2461	624.92
7, 10, 13	6400.00	7499.03	2754	5686.09
7, 10, 13	6400.00	7499.03	2755	1188.02
8, 11, 14	12200.00	14373.10	2461	13.85
8, 11, 14	12200.00	14373.10	2753	61.29
8, 11, 14	12200.00	14373.10	2754	12423.20
8, 11, 14	12200.00	14373.10	2755	1874.76

A split landuse for MIGS cover was performed in the original SWAT+ model set up

20% FRSD / 50% FRSE / 15% RNGB / 15% FRST

connection fail due to incompatibility SWAT and gwflow.

This split is not distributed spatially, only internally in the areas of the HRU.con file

1. Model set up

HRUs shape→ Split + Simplification

PROBLEM 2

Underestimation of areas in the HRUS shp

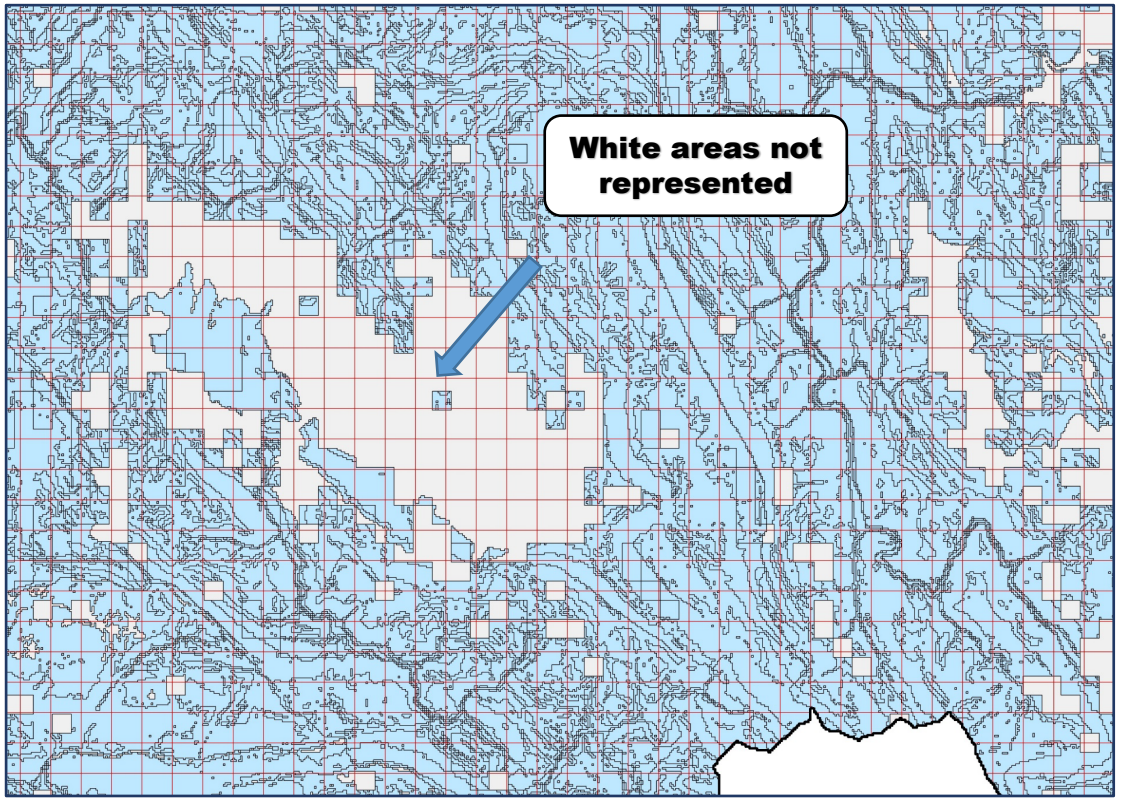
↓

A simplification of Landuse/Soil/Slope was performed in the model set up

Threshold: 10/10/10 [%].

↓

Underestimation of the HRUs areas due to areas not represented in the shape



1. Model set up

HRUs: Combined solution

STEP 1

Calculate the area that is missing in the shapefile comparing it with the HRU.con file

Sum area HRU.con	Sum shape area
726839.02	**575460.52**

151378.50 ha simplified

Around 20%

HRU.con file

hru.con: written by SWAT+ editor v2.1.4 on 2022-11-22

id	name	gis_id	area
1	hru0001	1	2.97516
2	hru0002	2	1.58675
3	hru0003	3	3.29957
4	hru0004	4	2.09035
5	hru0005	5	2.94649
6	hru0006	6	0.26247
7	hru0007	7	0.14998
8	hru0008	8	0.28746
9	hru0009	9	0.65616
10	hru0010	10	0.37495
11	hru0011	11	0.71866
12	hru0012	12	0.19685
13	hru0013	13	0.11249
14	hru0014	14	0.21560
15	hru0015	15	94.48197
16	hru0016	16	205.57278
17	hru0017	17	15.00562
18	hru0018	18	23.17821
19	hru0019	19	3.98251
20	hru0020	20	93.86933
21	hru0021	21	410.84357
22	hru0022	22	166.41974

Contains the area of the HRUs considering those simplified areas.

Distributed across all HRUs

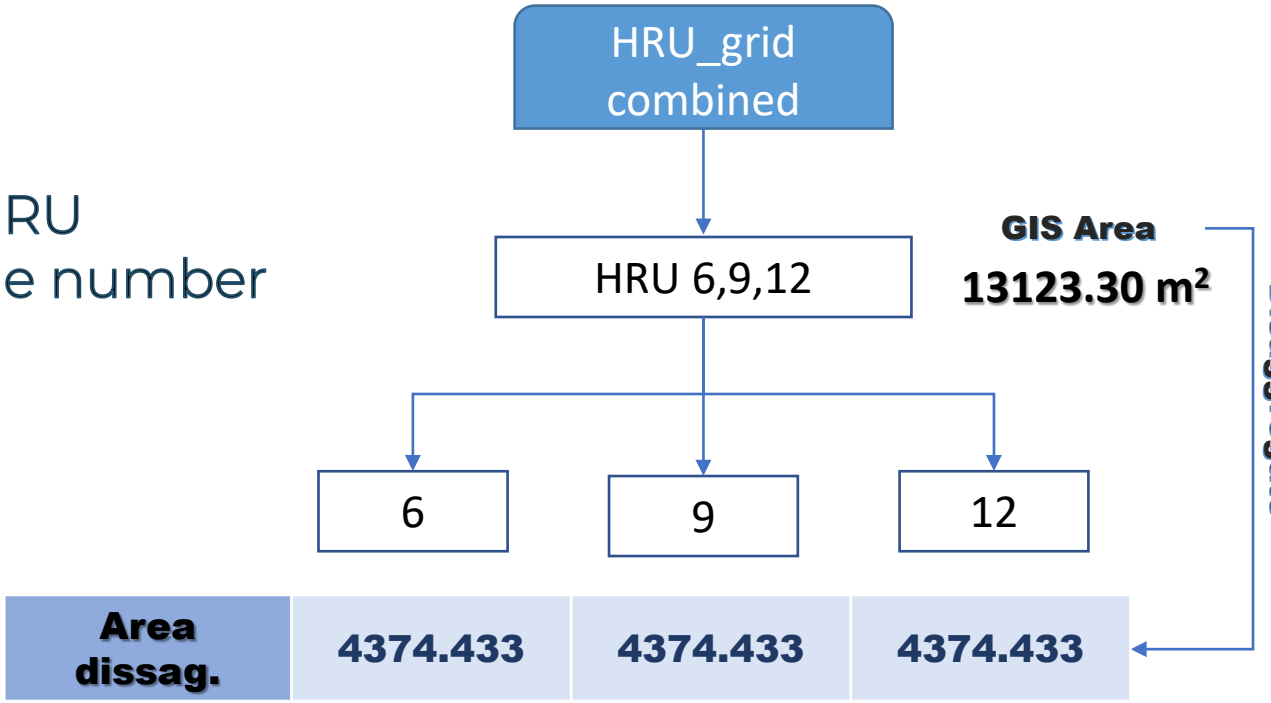
1. Model set up

HRUs: Combined solution

STEP 2

Disaggregate all joined HRUs in the GRID-HRU connection table dividing the GIS area by the number of partitions in the HRU

gis_id	poly_area	HRUS
1	28121.363	1
2	14998.052	2
3	31870.868	3
4	18747.580	4
5	27496.422	5
6	4374.433	6, 9, 12
7	2499.676	7, 10, 13
8	4791.032	8, 11, 14
9	4374.433	6, 9, 12
10	2499.676	7, 10, 13
11	4791.032	8, 11, 14
12	4374.433	6, 9, 12
13	2499.676	7, 10, 13
14	4791.032	8, 11, 14
15	621169.490	15



Get a table HRUs with a unique identifier

R Studio

1. Model set up

HRUs: Combined solution

$$\text{Weights} = \frac{\text{Area HRU.con}}{\text{Area shape}}$$

STEP 3

Apply a weight to the GIS area of each HRU and HRU dissagregated taking into account the recalculated area of each HRU in the HRU.con file, so the final area matches with the real basin area

HRU	6	9	12
Area shape	4374.433	4374.433	4374.433
Weights	0.6	1.5	0.45
Area weighted	2624.7	6561.6	1968.5

MODEL READY TO RUN!!!

Area weighted = Weights * Area shape

hru.con: written by SWAT+ editor v2.1.4 on 2022-11-22 14:57 for SWAT+ rev.60.5.4

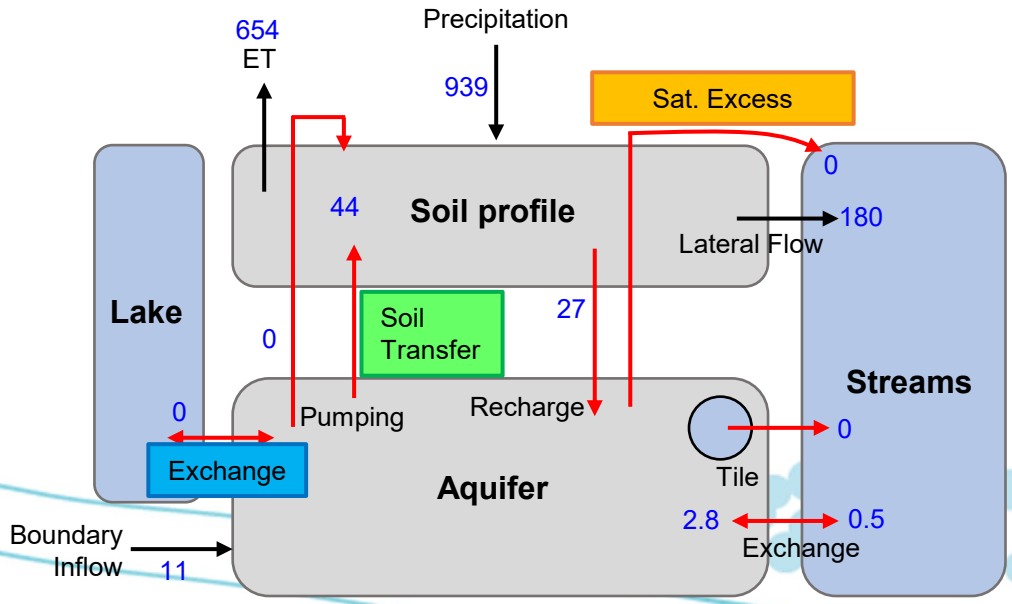
id	name	gis_id	area	lat	lon	elev
6	hru0006	6	0.26247	40.98521	-2.29867	1095.23810
9	hru0009	9	0.65616	40.98521	-2.29867	1095.23810
12	hru0012	12	0.19685	40.98521	-2.29867	1095.23810

2. Run default model

Key procces

Flags: simulate different groundwater interactions

```
1 flag: groundwater  --> soil    transfer
1 flag: groundwater  saturation  excess  flow
0 flag: external groundwater pumping
0 flag: groundwater tile drainage
1 flag: groundwater-reservoir exchange
0 flag: groundwater-wetland exchange
0 flag: groundwater-floodplain exchange
0 flag: canal seepage to groundwater
0 flag: groundwater solute transport
```



Key parameters

kaqu	Aquifer hydraulic conductivity	(m/day)
syaqu	Aquifer specific yield	
bedK	Streambed hydraulic conductivity	(m/day)
bedthick	Streambed thickness	(m)
beddeph	Streambed deph	(m)

2. Run default model

- Set initial values for parameters in **gw.data**
  - 2 aquifer zones: CRB and DETR
  - 300 m thickness
  - WT→ -10 m depth.
- Grid HRUs modified and channels connection inputs

	CRB	DET
Kaqu (m/day)	0.05	0.01
Syaqu	0.002	0.08
bedK (m/day)	0.0005	0.0005
Bedthick (m)	2	1.5
Beddeph (m)	5	

```
input for gwflow module
basic information
structured
  400.0000     grid cell size (m)
       269          293 number of rows and columns in the grid
         2 boundary condition: 1=constant; 2=no flow
         1 recharge connection type (1=HRU-cell; 2=LSU-cell)
         0    flag:   groundwater --> soil    transfer
         0    flag:   groundwater saturation  excess  flow
         0 flag: external groundwater pumping
         0 flag: groundwater tile drainage
         0 flag: groundwater-reservoir exchange
         0 flag: groundwater-wetland exchange
         0 flag: groundwater-floodplain exchange
         0 flag: canal seepage to groundwater
         0 flag: groundwater solute transport
  0.25     time step to solve groundwater balance
         1           1           1
       293 number of columns for writing out to file
```

Configuration No Flags

Simulate an aquifer contribution to streamflow similar to SWAT+

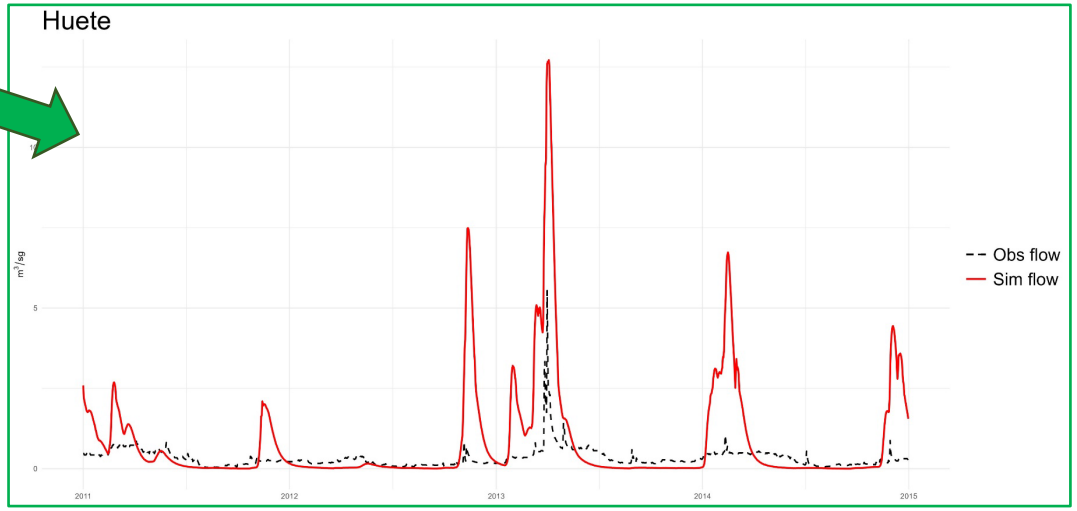
Streams baseflow from direct aquifer groundwater discharge

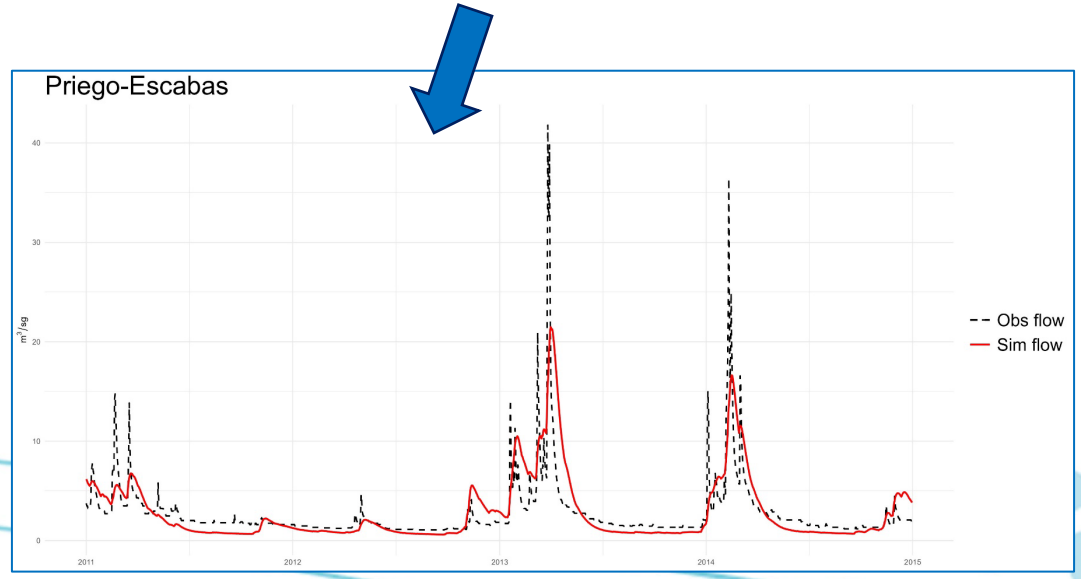
2. Run default model

- Calibrated SWAT+ parameters (**calibration.cal** from previous calibrated model)
- Run a default simulation
- Main observation
  - No baseflow in DETR catchments (High peaks)
  - Baseflow in CRB catchments

calibration.cal file

```
Number of parameters:
38
NAME          CHG_TYPE                VAL
esco            absval 0.7586838950000
epco            absval 0.0581856550000
cn2             pctchg -5.315343099000
awc             pctchg -26.34781564000
perco           absval 0.8452101060000
z               pctchg -55.62501950000
k               pctchg -65.14190098000
cn3_swf         abschg 0.0098775210000
bd              pctchg -3.116742251000
latq_co         abschg -0.283268407000
ovn             pctchg -4.768298565000
lat_ttime       absval 10.000000000000
```





3. Sensitivity analysis

	Default	↓↓	↓	↑	↑↑
kaqu1	0.05	0.005	0.025	0.075	0.15
kaqu2	0.01	0.001	0.005	0.015	0.03
syaqu1	0.002	0.0002	0.001	0.003	0.006
syaqu2	0.08	0.008	0.04	0.12	0.24
bed_k1	0.0004	0.000005	0.00005	0.005	0.05
bed_k2	0.0004	0.000005	0.00005	0.005	0.05
bed_th1	2	0.2	1	3	6
bed_th2	1.5	0.15	0.75	2.25	4.5
bed_dep	5	0.5	2.5	7.5	15

- Explore the parameters influence (one at a time = 36 sims + default)
- Tested 4 values: 2 above 2 below
- Sensitivity evaluation on:
  - Basin gw_fluxes
  - Station streamflow values

3. Sensitivity analysis

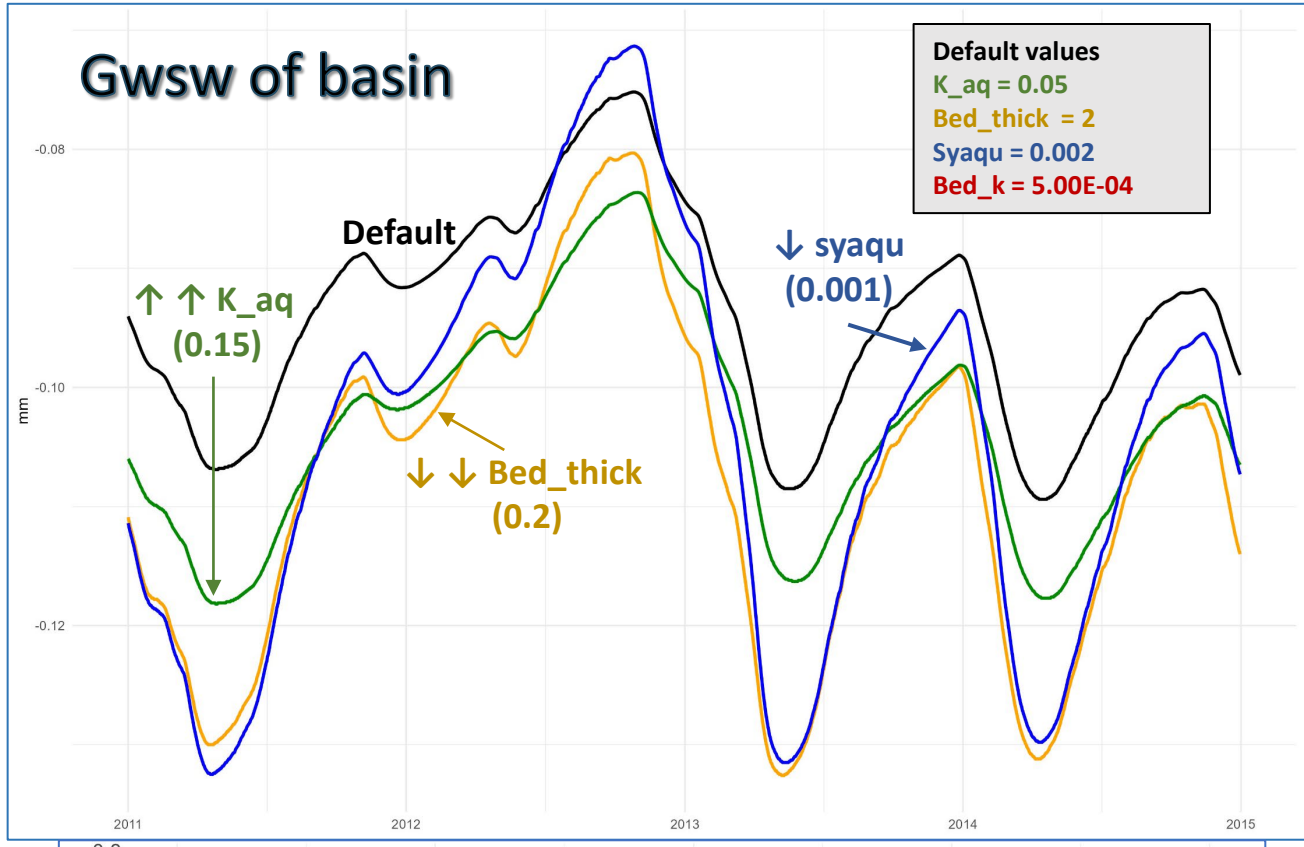
Gw fluxes at basin scale

Main fluxes to allow gw in streams

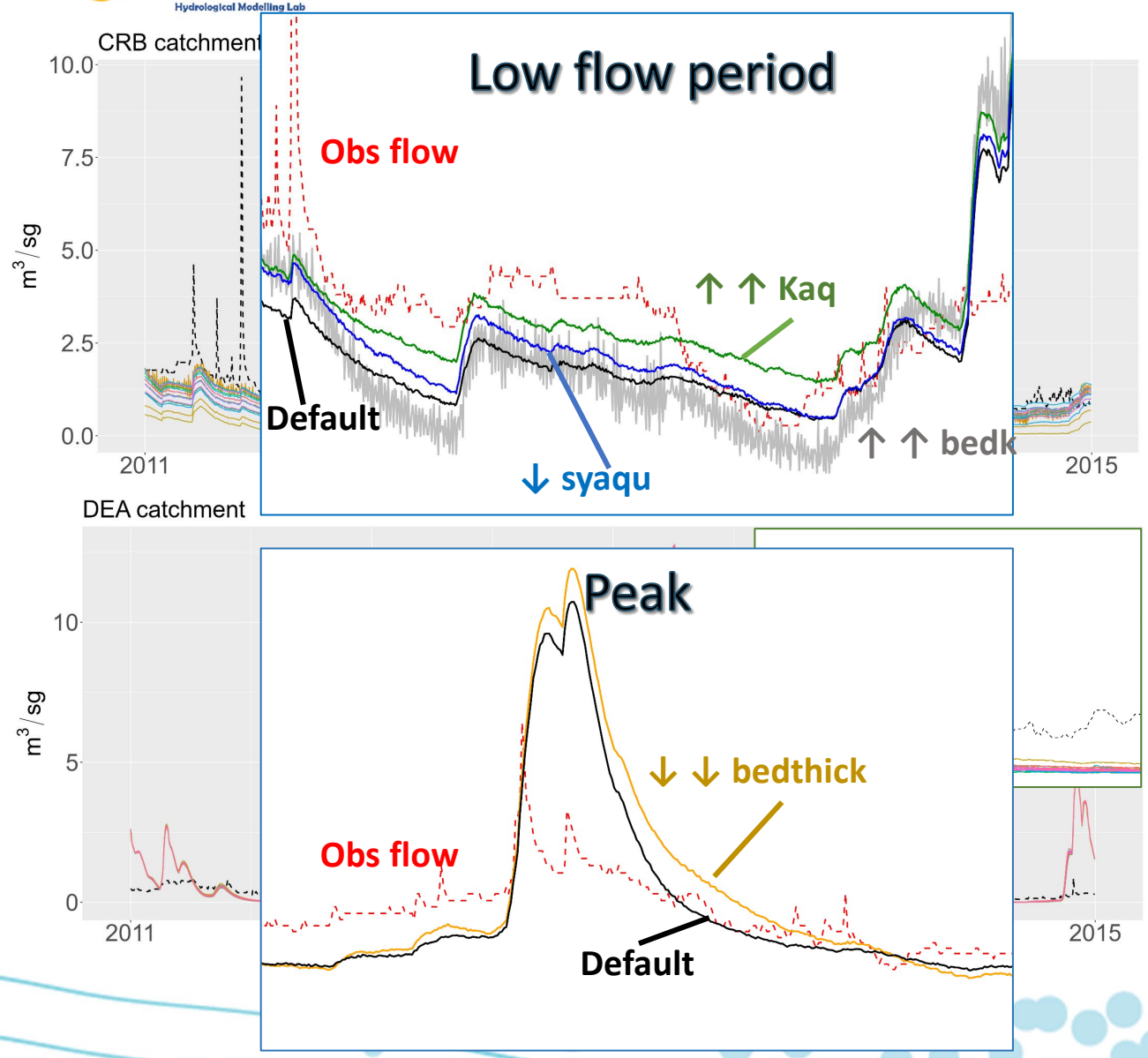
- **Gwsw**: groundwater discharge to streams

Main remarks

- ↑ K_aqu favors the increase of gwsw
- ↓ bed_thick and ↓ sy_aqu favors the increase of peaks of gwsw
- ↑ bed k values generate too much gw and fast peaks responses in gwsw (NOT CONVENIENT)



3. Sensitivity analysis



Streamflow

High sensitivity in CRB catchments

Low sensitivity in low flows in DETR catchments

Relevant remarks in CRB streamflow

- Increase K_aqu and reduce sy_aqu to facilitate the entry of gw in streams
- High bedk generates daily peaks in CRB subcathments
- Decrease bedthick affects the recession of water after peaks

Conclusions

- A realistic gwflow model of the headwaters Tagus basin has been built.
- A methodology to allow the use of a simplified HRUs shp has been designed and implemented , which can help other modelers.
- A simple sensitivity analysis was carried out to test the influence of the parameters.
- The CRB aquifer is more sensitive because of its greater relevance of groundwater
- k affected the amount of groundwater while sy, bed_thick and bed_k had an influence on seasonal variability.

Forthcoming work

1. Calibration will be implemented when achieving steady state in water table
2. Checking the response of the model activating flags like soil transfer or satex excess flow
3. Target variables: Streamflow and piezometric levels.
4. Assessing the option of a combined calibration with SWAT+ parameters (calibration.cal).

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Thanks

for your attention!