Application of the SWAT model to Mediterranean flash floods

Does the use of fine climate stations grid and sub-basins delineation improve the modelling of river discharge and sediments fluxes at hourly time-step?

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2015 SWAT Conference, Pula, June 24-26

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Context

- Global change is expected to increase the frequency of intense rainfall events and consequent **flash floods** across the Mediterranean coastal basins in the next decades.
- Some complex physically-based distributed models are able to simulate hydrological processes at the flood time-scale but they do not capture below-ground processes.
- The SWAT model has recently been upgraded to sub-daily time-step calculations. However, its sub-daily module has only been tested in small catchments (~1 km^2).

Objectives

- The objectives of this study were :

(1) to assess the ability of the SWAT model to simulate discharge at hourly time-step in a ~1400 km² river basin

(2) to assess the possible gain of model's performance when using fine grids of climate stations and sub-basins representation.

Green&Ampt infiltration equation

SOL_K
CN2

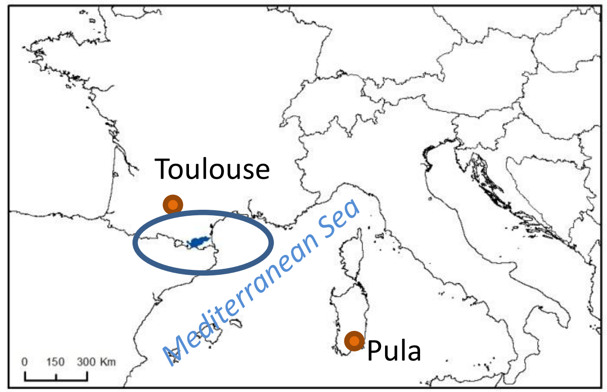
SOL_CLAY
SOL_SAND
SOLB_BD

SOL_AWC
SOLB_BD

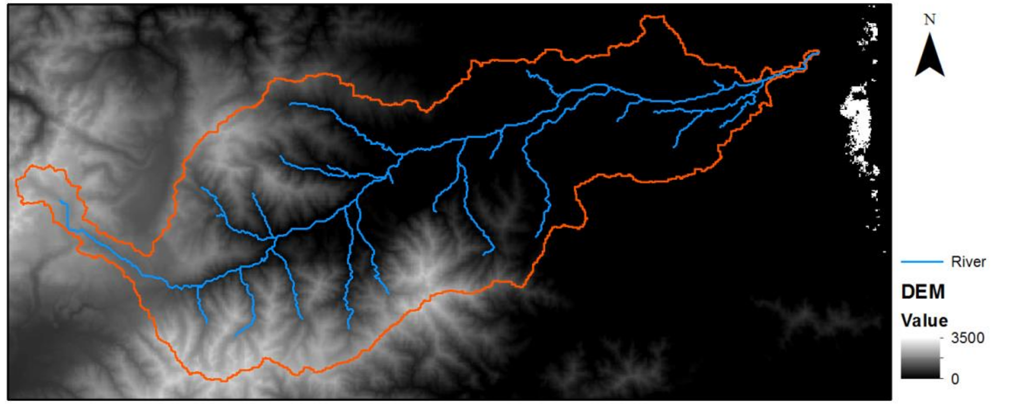
$$f_{inf,t} = K_e \cdot \left(1 + \frac{\Psi_{wf} \cdot \Delta\theta_v}{F_{inf,t}} \right)$$

where f_{inf} is the infiltration rate at time t (mm/hr), K_e is the effective hydraulic conductivity (mm/hr), Ψ_{wf} is the wetting front matric potential (mm), $\Delta\theta_v$ is the change in volumetric moisture content across the wetting front (mm/mm) and F_{inf} is the cumulative infiltration at time t (mm H_2O).

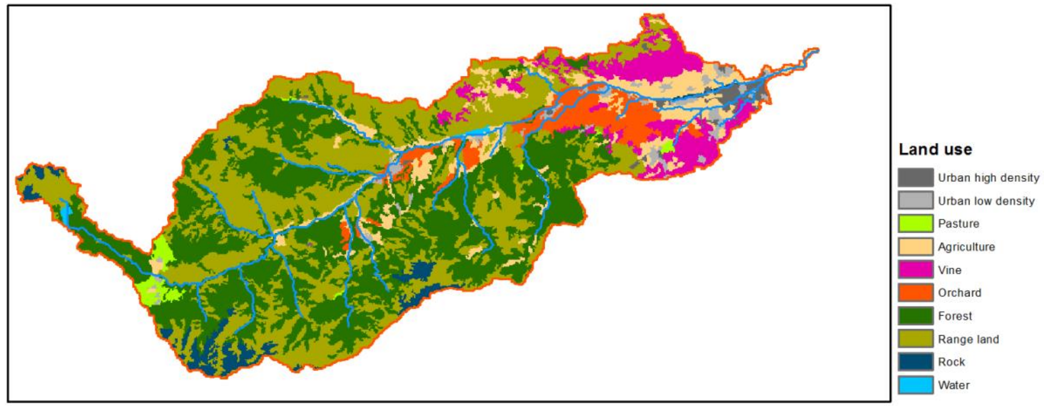
Data for model set up



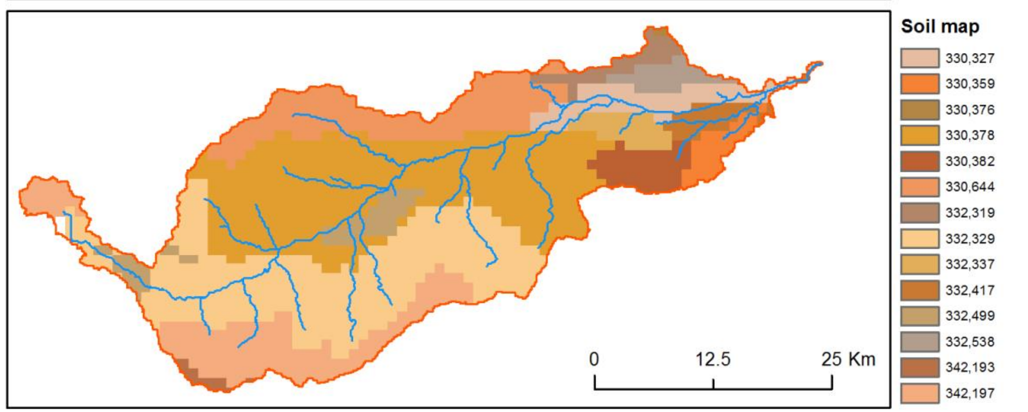
DEM: SRTM 90m



Land use: Corine Land Cover
-> mostly range land and forests

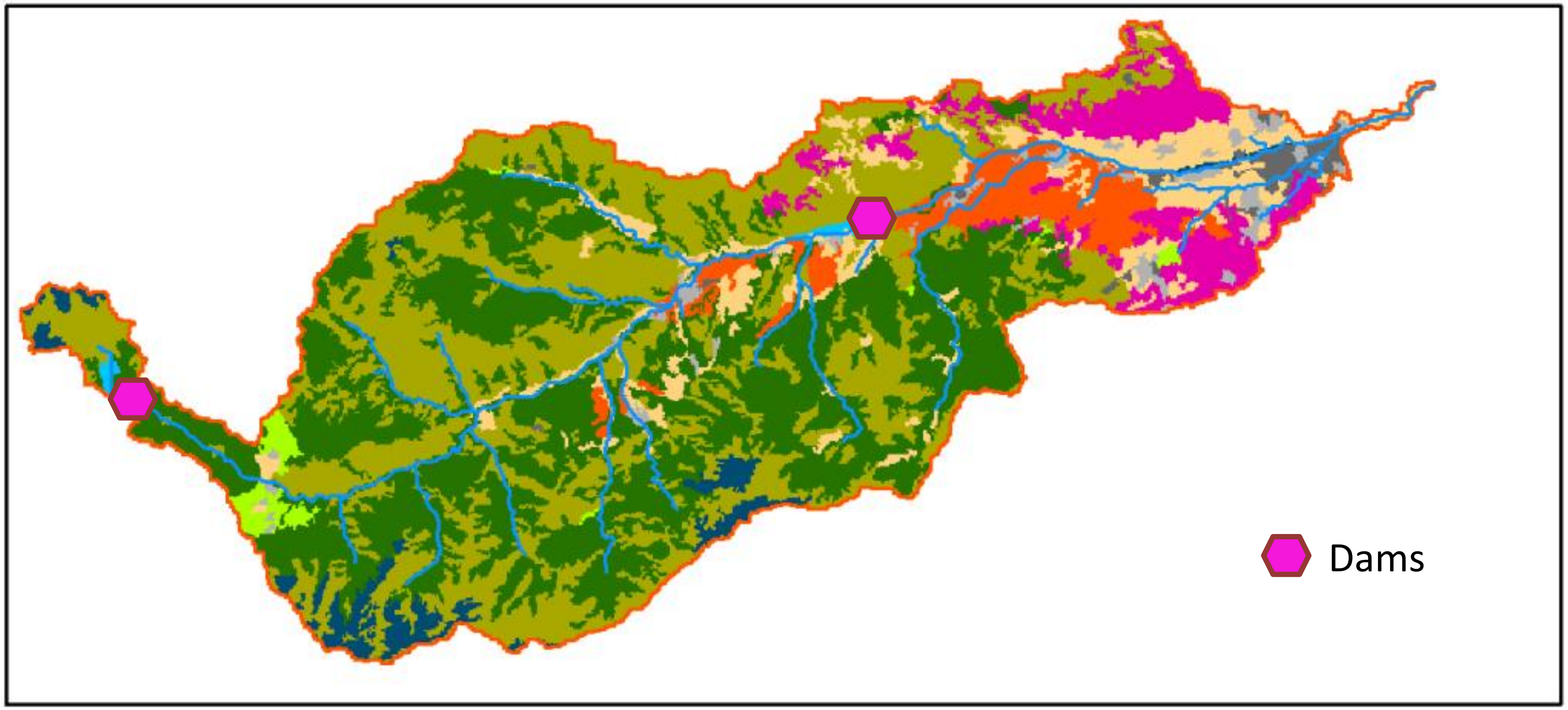


Soil: FAO
+ associated INRA soil properties
-> Mostly shallow (1.4m) sandy soils



Data for model set up

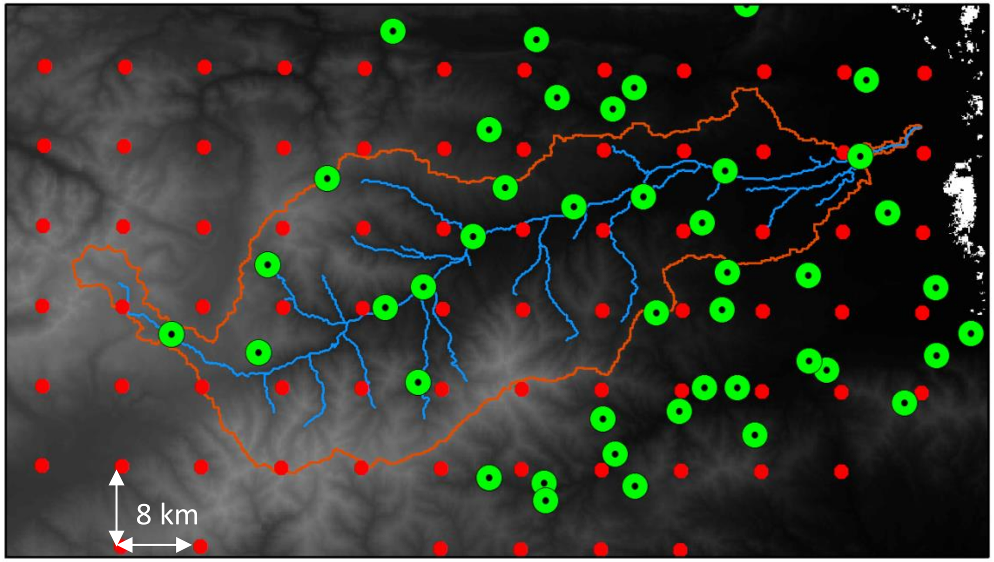
Daily discharge out of 2 dams
- Vinça (irrigation): 24 hm^3, data from 2000 to 2013
- Bouillouses (hydropower): 17 hm^3, waiting for the data from EDF

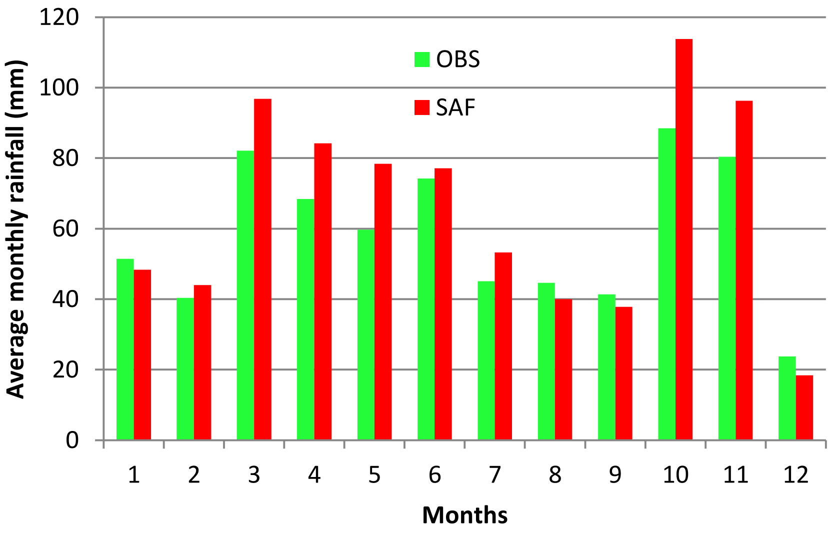


Data for model set up

Climate data

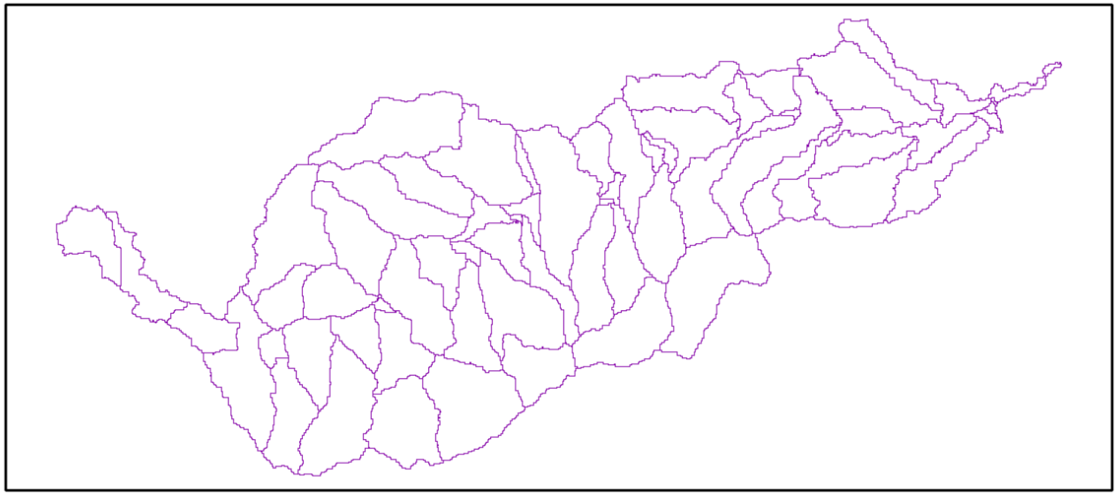
- Daily temperature, humidity, wind, radiation (PET): SAFRAN
- **Hourly rainfall**: measured (OBS) / SAFRAN (SAF)



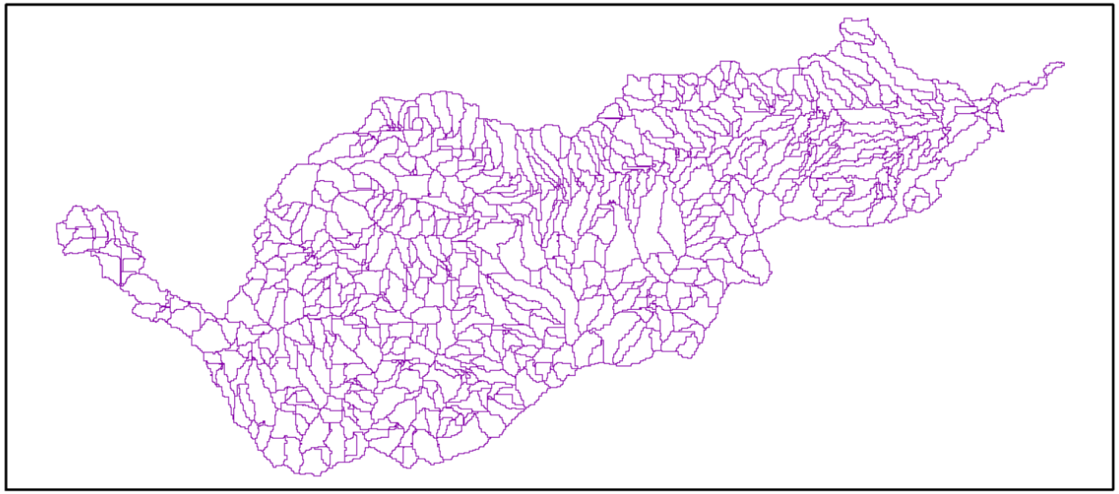


2 sub-basin delineations

Minimal drainage area: **1500 ha**
66 subbasins, 549 HRU

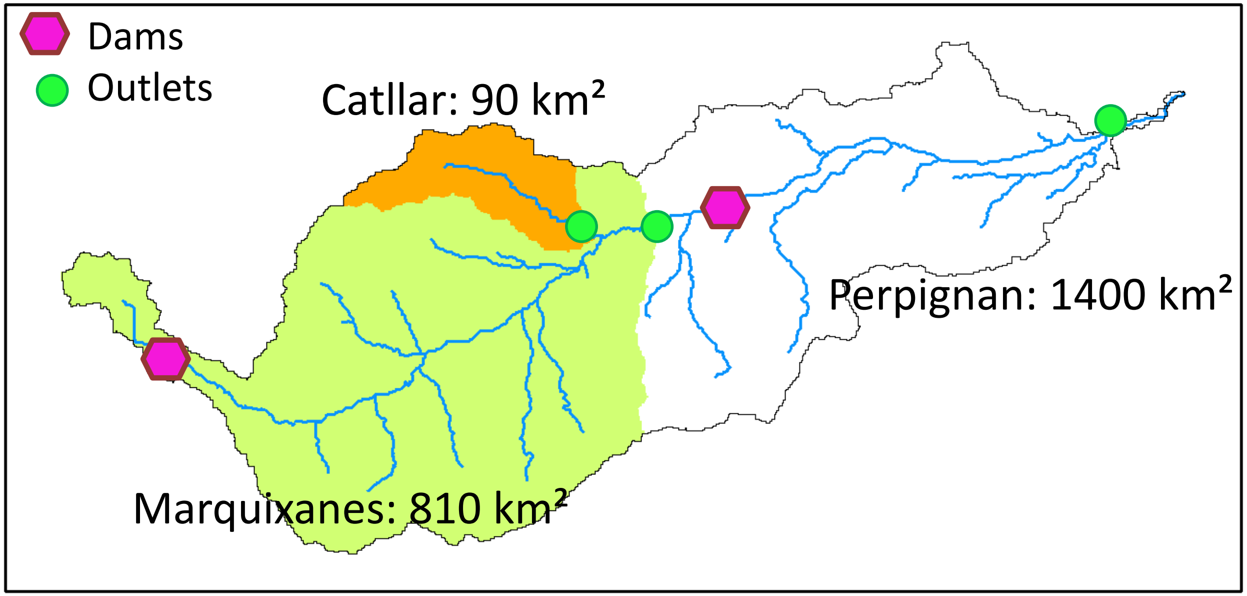


Minimal drainage area: **100 ha**
691 subbasins, 2342 HRU



Calibration/validation measured data

Subdaily discharge in 3 gauging stations (Banque Hydro) -> **focus on 3 embeded catchments**
number of measures 2009-2011: Catl: 14977; Marq: 18765; Perp: 25909



Calibration/validation periods for discharge simulation:

- warm-up 2005-2009
- calibration 2009-2011
- validation 2012-2015

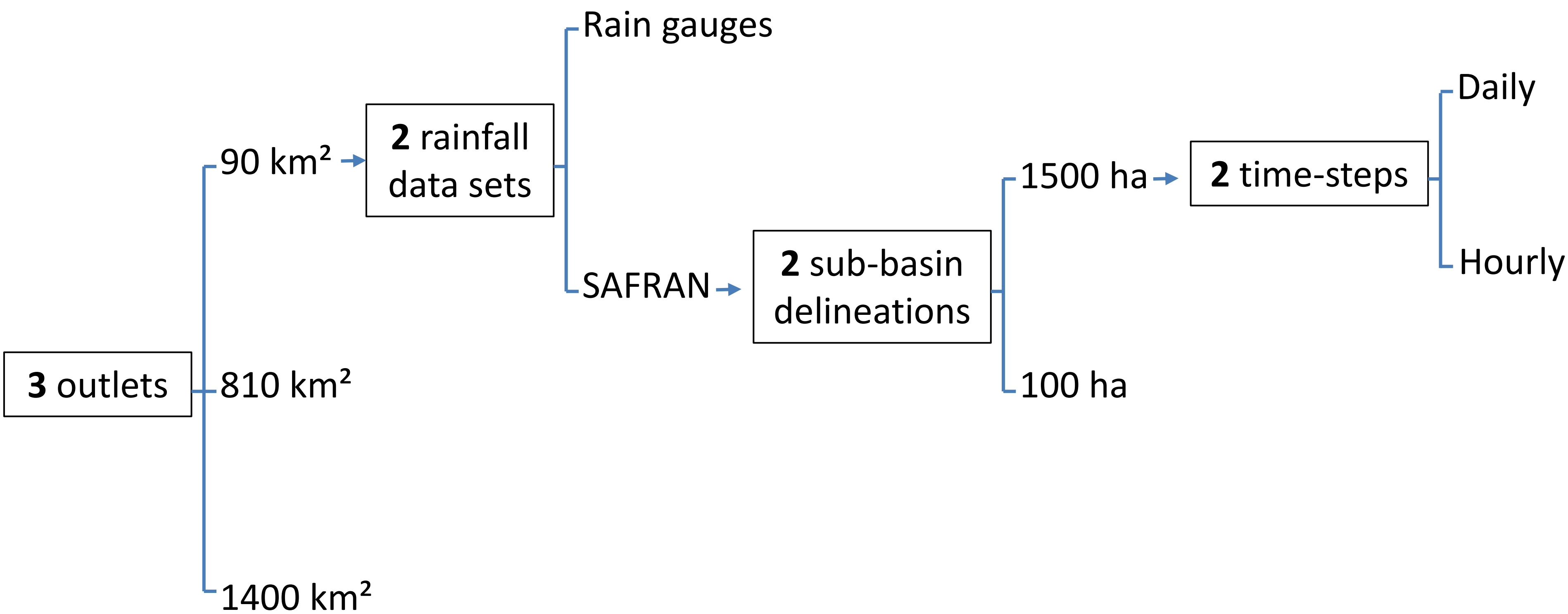
Parameters for SWAT-CUP set up

21 parameters

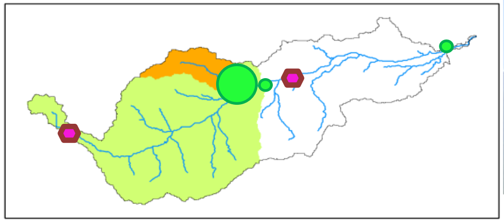
Parameter			Min	Max
CN2	.mgt	R	-0.1	0.1
ALPHA_BF	.gw	V	0.01	1
GW_DELAY	.gw	V	0	500
GW_REVAP	.gw	V	0.02	0.2
GWQMN	.gw	V	0	5000
RCHRG_DP	.gw	V	0.01	0.99
REVAPMN	.gw	V	0	500
CH_K2	.rte	V	0.01	10
CH_N2	.rte	V	0.025	0.15
CH_K1	.sub	V	0.01	10
CH_N1	.sub	V	0.025	0.15
ESCO	.hru	V	0.7	0.9
EPCO	.hru	V	0.7	1
LAT_TTIME	.hru	V	0	180
CANMX	.hru	V	0	100
OV_N	.hru	V	0.01	0.6
SOL_K	.sol	R	0	9
SOL_AWC	.sol	R	-0.1	0.1
SOL_BD	.sol	R	-0.1	0.1
SOL_CBN	.sol	R	-0.1	0.1
SURLAG	.bsn	V	0.05	24

-> daily and hourly autocalibration

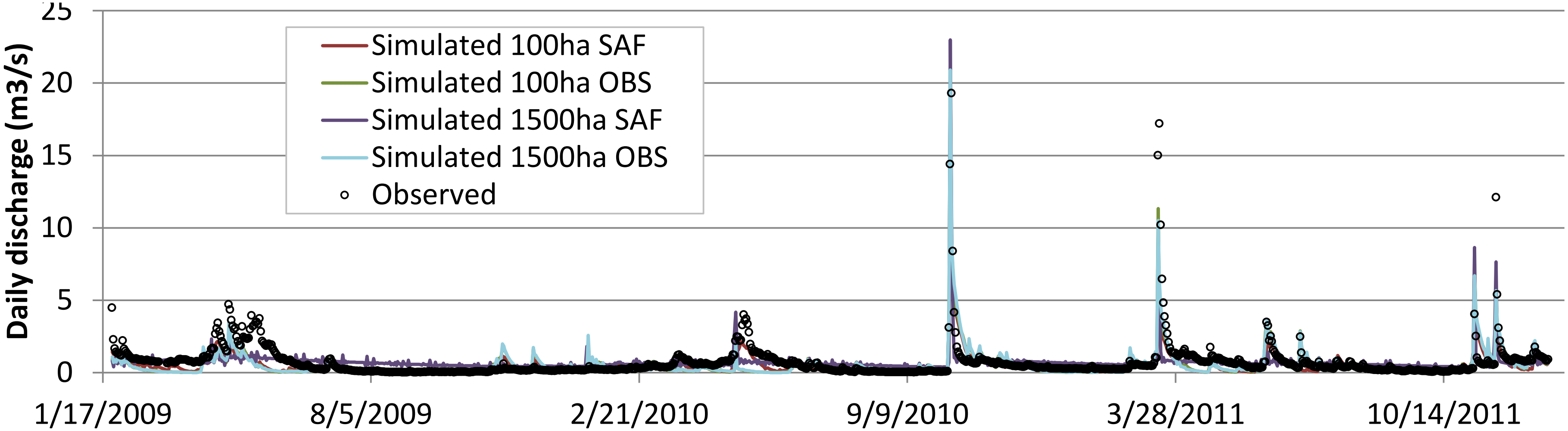
Experimental design

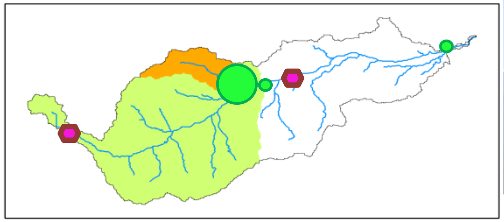


24 combinations -> 24 calibrations (2009-2011)



Daily discharge in Catllar (90 km^2)





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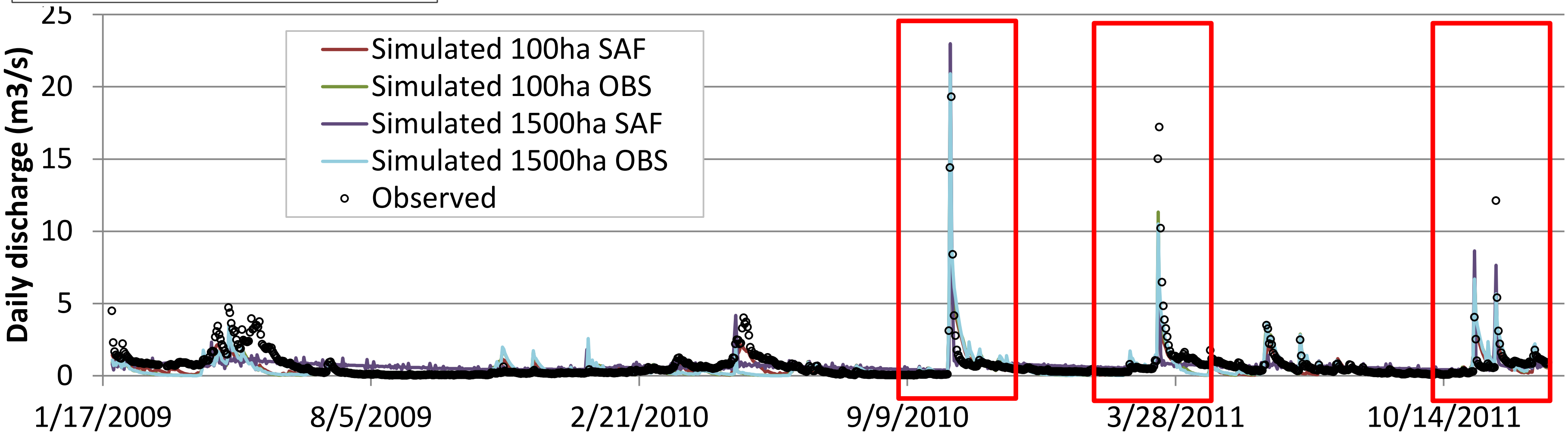
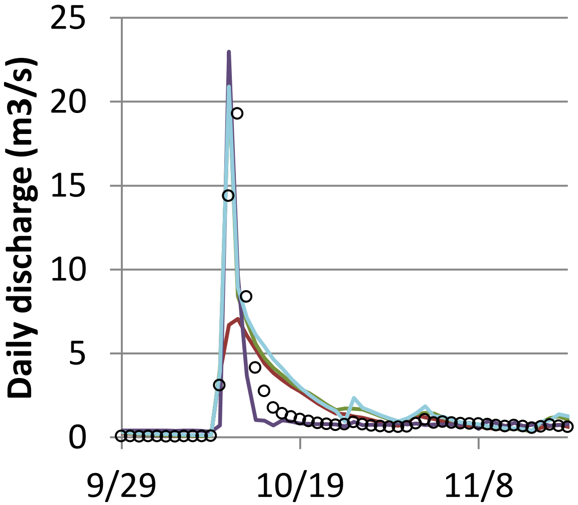
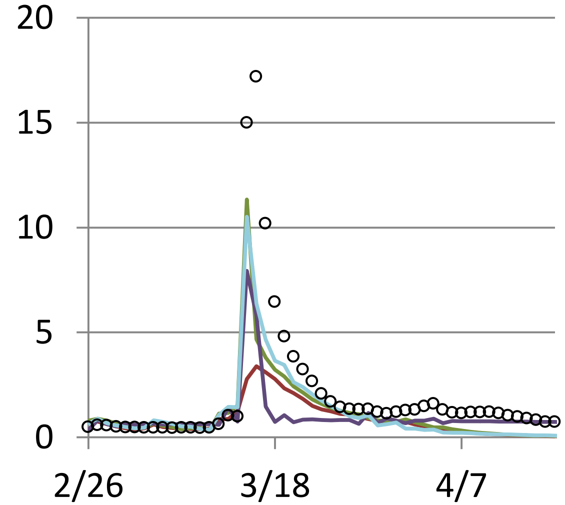
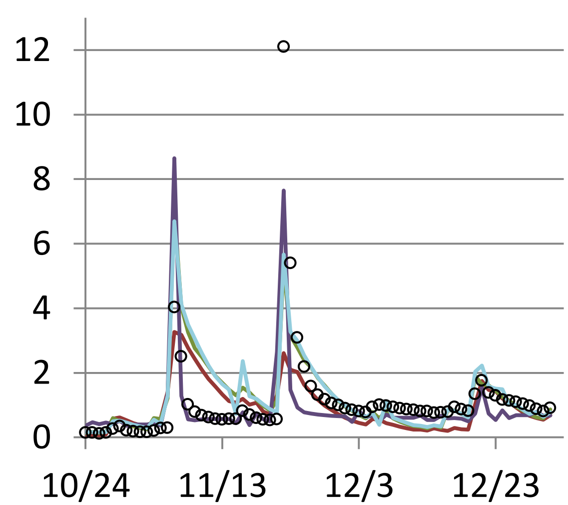






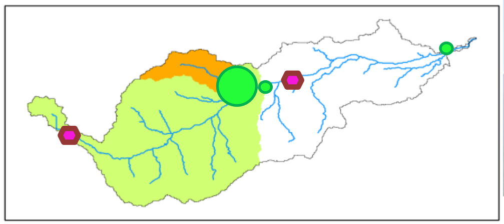


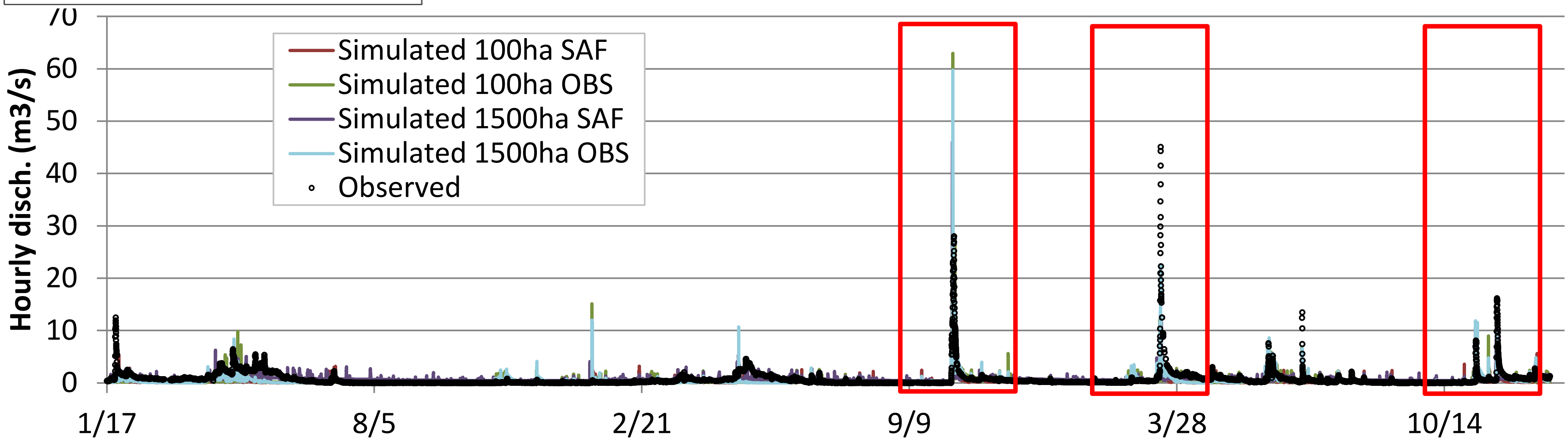
NASH	OBS	SAF
100 ha	0.65	0.59
1500 ha	0.65	0.64

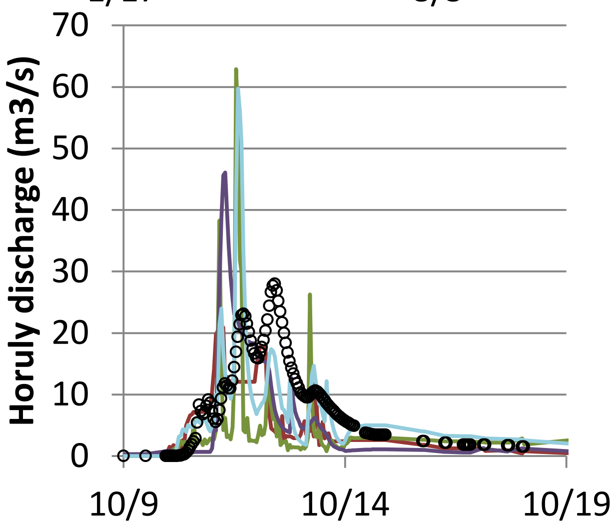
NASH	OBS	SAF
100 ha	0.56	0.22
1500 ha	0.64	0.40

NASH	OBS	SAF
100 ha	0.48	0.28
1500 ha	0.50	0.55

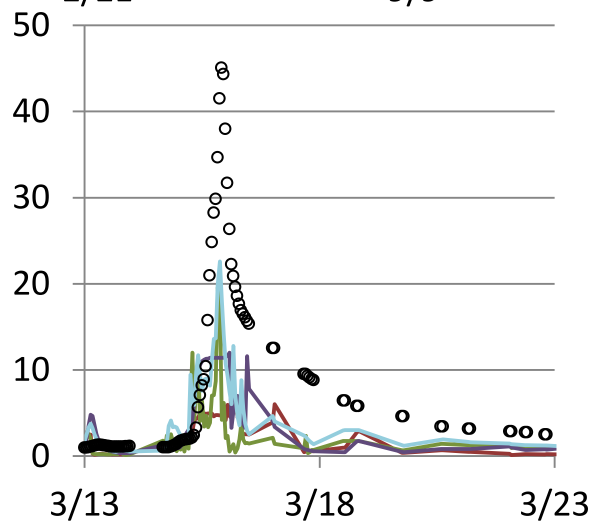
Hourly discharge in Catllar (90 km²)



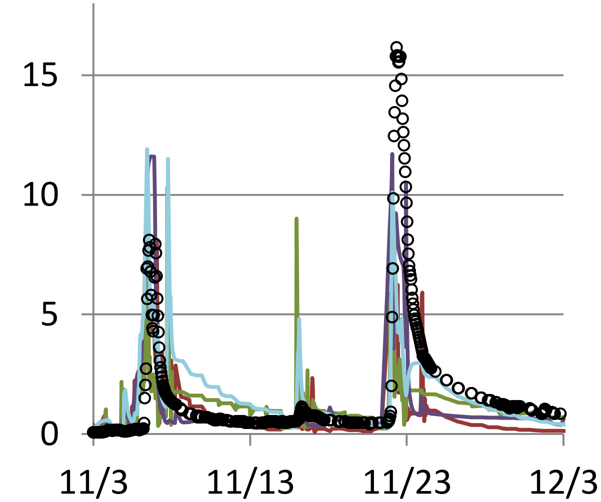




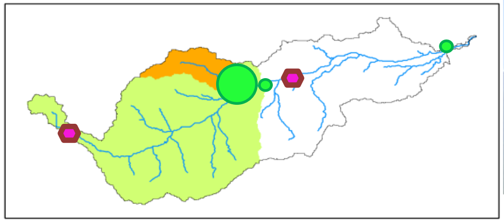
NASH	OBS	SAF
100 ha	-0.97	-0.02
1500 ha	-0.13	-0.41



NASH	OBS	SAF
100 ha	-0.11	-0.14
1500 ha	0.36	0.23



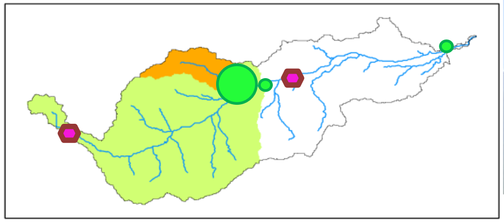
NASH	OBS	SAF
100 ha	0.06	0.18
1500 ha	0.28	0.40



Summary of the performances

2009-2011

Outlet	Meteo data	Min. drain. area	Daily NS	Hourly NS
90 km²	SAF	1500 ha	0.50	0.38
		100 ha	0.45	0.29
	OBS	1500 ha	0.55	0.40
		100 ha	0.52	0.14
810 km²	SAF	1500 ha	-0.86	-1.00
		100 ha	0.46	0.18
	OBS	1500 ha	-0.55	-1.12
		100 ha	-0.75	-0.93
1400 km²	SAF	1500 ha	0.35	0.24
		100 ha	0.78	0.68
	OBS	1500 ha	0.56	0.38
		100 ha	0.62	0.52



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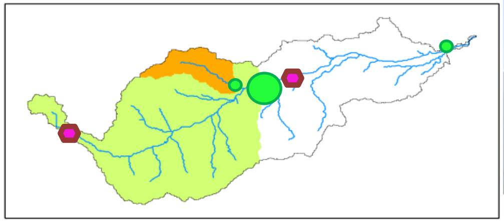

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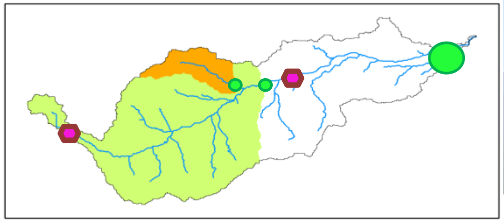
Missing upstream dam data?



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Daily discharge out of dam controls the discharge d/h

Most sensitive parameters

Outlet	Meteo data	Min. drain. area	Daily	Hourly
90 km²	SAF	1500 ha	LATTIME (116) CN2 (0.06) GWQMN (475)	CN2 (0.06) SOL_K (0.31) LATTIME (116)
		100 ha	LATTIME (6) CN2 (0.06) GWQMN (3875)	CN2 (0.08) LATTIME (2.7) SOL_K (3)
	OBS	1500 ha	SOL_K (8) LATTIME (6) SOL_AWC (0.04)	SOL_K (6) CH_N2 (0.13) SURLAG (16)
		100 ha	SOL_K (8) LATTIME (6) GWQMN (3875)	SOL_K (6) CN2 (-0.04) SURLAG (16)
810 km²	SAF	1500 ha	SOL_K (5) CN2 (-0.05) SOL_AWC (0.06)	SOL_K (5) CH_N2 (0.14) CN2 (-0.05)
		100 ha	SOL_K (5) GWQMN (625) ALPHA_BF (0.69)	SOL_K (6) SURLAG (9) ALPHA_BF (0.72)
	OBS	1500 ha	SOL_K (5) CN2 (-0.05) CH_N2 (0.14)	SOL_K (5) CH_N2 (0.14) CN2 (-0.05)
		100 ha	SOL_K (6) CN2 (0.01) SOL_BD (0.04)	SOL_K (6) CN2 (0.01) SOL_BD (0.04)
1400 km²	SAF	1500 ha	SOL_K (5) RCHRG_DP (0.50) GWQMN (625)	CH_N2 (0.13) RCHRG_DP (0.28) GWQMN (4775)
		100 ha	SOL_K (3) CH_N2 (0.05) RCHRG_DP (0.04)	CH_N2 (0.15) RCHRG_DP (0.09) CN2 (-0.02)
	OBS	1500 ha	CH_N2 (0.05) SOL_K (0.05) GWQMN (2375)	CH_N2 (0.11) RCHRG_DP (0.64) GWQMN (4275)
		100 ha	CH_N2 (0.15) LATTIME (26) SOL_BD (0.04)	CH_N2 (0.11) LATTIME (33) SOL_K (8)

9 parameters out of 21

Most sensitive parameters

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SOL_K > CN2 > CH_N2

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		100 ha	CH_N2 (0.15) LATTIME (26) SOL_BD (0.04)	CH_N2 (0.11) LATTIME (33) SOL_K (8)

SOL_K > LAT_TTIME > CN2

SOL_K > LAT_TTIME

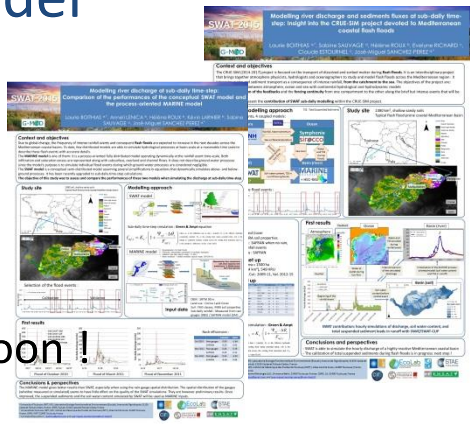
CH_N2 > RCHRG_DP

Conclusions

- For a 90 km^2 basin without dam:
  - Hourly simulations catch sub-daily peaks but Nash are lower than daily Nash
  - Rainfall distribution and sub-basin delineation are sensitive model inputs
    - Simulations with PCP from rain gauges seems more reliable than modelled PCP grids
    - It seems there is no need to discretize the basin at 100 ha
  - SOL_K appears to be the most sensitive parameter and needs to be accurately estimated
- For bigger basins with dams:
  - The quality of the hourly simulation depends on the quality of the daily out-of-dam discharge data (*.day file)

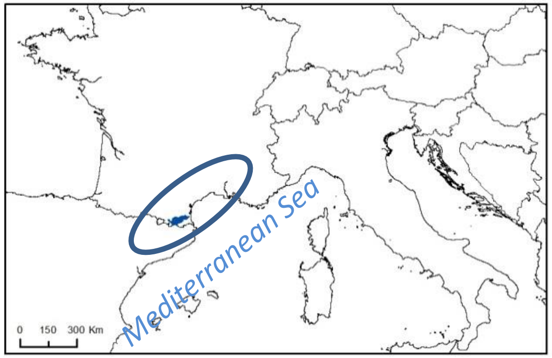
Perspectives

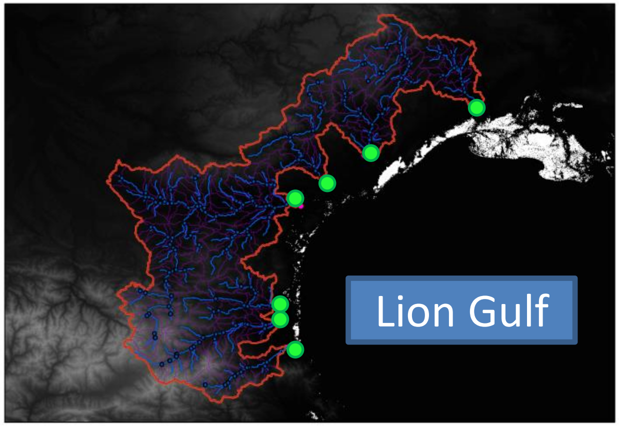
- Simulation of suspended sediments
- Coupling with the process oriented MARINE model
  - Comparison of the hourly simulated discharge. If ok:
  - Soil water content to initialize the MARINE model
  - Later also suspended sediments in runoff



Come and see the posters this afternoon !

- Application to the other coastal flash-flood prone basins of the Lion Gulf



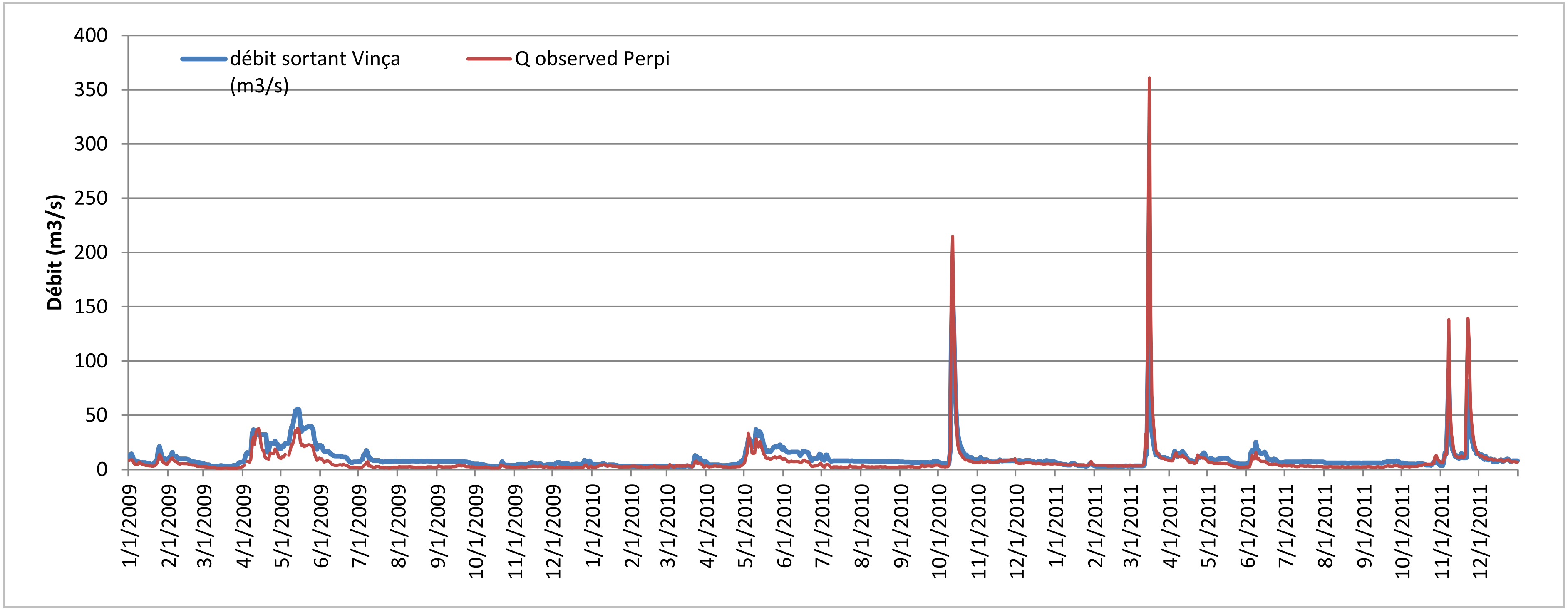


Thank you for your attention !

l.boithias@gmail.com

Effect of the daily discharge out of the Vinça dam…

… on the discharge in Perpignan



The calibration on Perpignan does not make much sense !