Evaluation of the precipitation time-step influence in streamflow and suspended sediment yield using SWAT in a small forested headwater catchment

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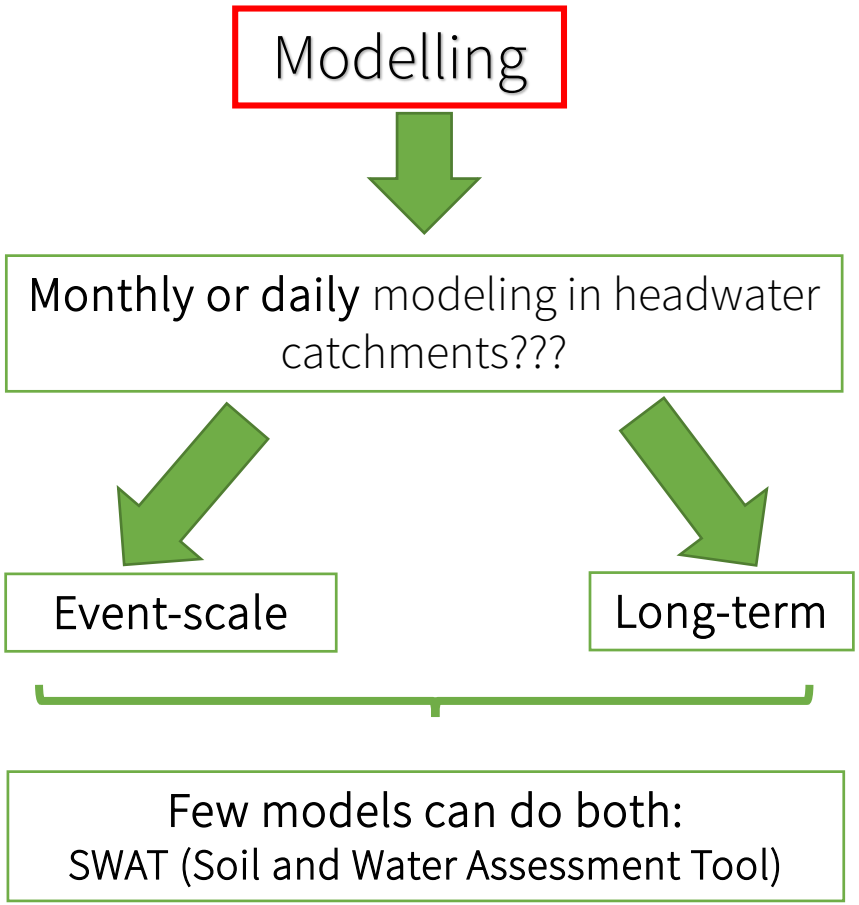
Headwater catchments

- Provide a significant proportion of **streamflow** to many **fluvial systems**
- **Contribute** in an important amount to the **global sediment discharge**
- **Influence in the water quality and quantity** that eventually is used downstream
- The research of the **hydrological processes** is relevant in the **catchment management practices**



HYPOTHESIS

- As much as lower time-step (precipitation):
  - Better streamflow and sediment yield results ➡ **analysis at event-scale**

OBJECTIVES

- Evaluate the **strengths and weaknesses of SWAT** model for **streamflow** and **suspended sediment simulation**:
  1) **Calibrate and validate** the streamflow and sediment simulation at **hourly** time-step (long-term)
  2) Evaluate the **hourly simulation results at daily** time-step (long-term)
  3) Evaluate the **hourly simulation performance in different storm event** (event-scale)
  4) Measure the **influence of the precipitation time-step** in the results (long-term)
     - *SWAT was used at daily time step in the study catchment*[1,2]

1Zabaleta, A., Meaurio, M., Ruiz, E. and Antigüedad, I., 2014. Simulation climate change impact on runoff and sediment yield in a small watershed in the Basque Country, northern Spain. J. Environ. Qual. 43, 235–245.

2Meaurio, M., Zabaleta, A., Uriarte, J.A., Srinivasan, R. and Antigüedad, I., 2015. Evaluation of SWAT models performance to simulate streamflow spatial origin. The case of a small forested watershed. J. Hydrol. 525, 326-334.

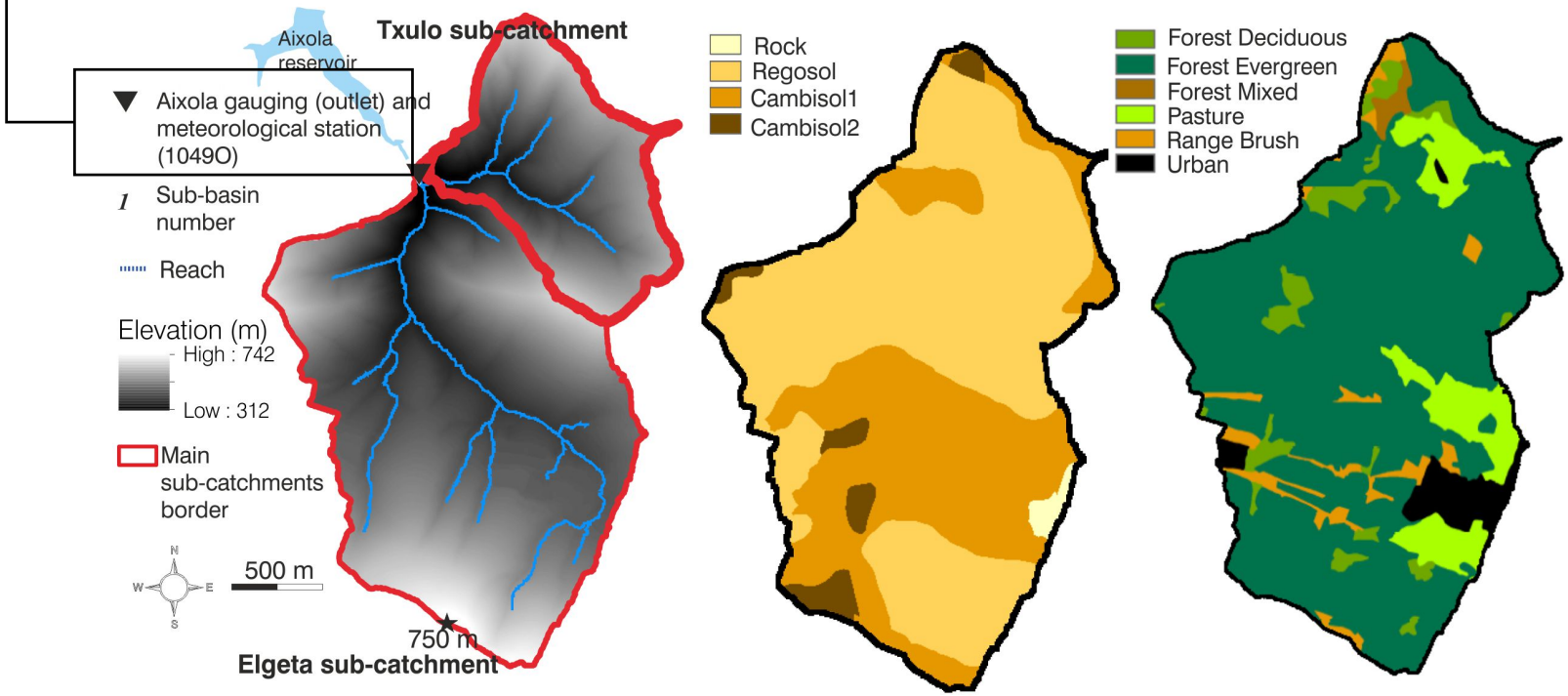
STUDY AREA

Hourly PCP:
2005-2010 val.
2010-2015 cal.

a) SUB-CATCHMENT DISTRIBUTION MAP

b) SOIL MAP

c) LANDUSE MAP

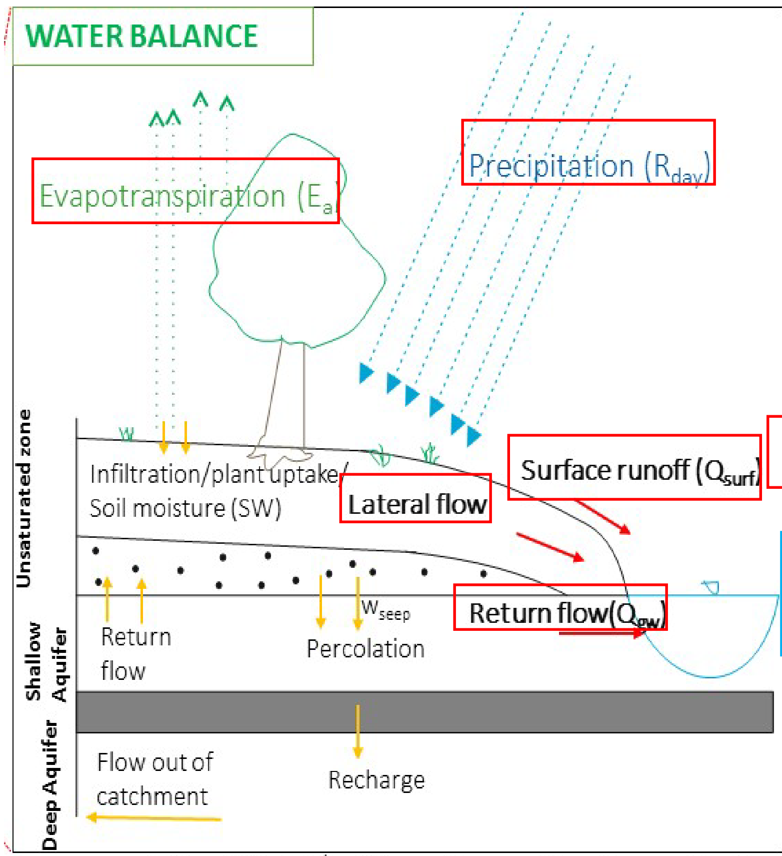


SWAT MODEL

SWAT considers the catchment hydrology in two major phases:

LAND PHASE

ROUTING PHASE



$$SW_t = SW_0 + \sum_{i=1}^{t}(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw})$$

WATER FLOW

Routing:

Infiltration and Surface runoff:

Daily -Manning method: to calculate volumetric rate and velocity of the water

Daily -SCS CN method: CN is Daily update according to antecedent soil conditions, Hydrological group and Slope

Sub-daily -Unit Hydrograph method: is used to route the surface runoff each time step

LAND PHASE

To route the discharge through the channel network:

ROUTING PHASE

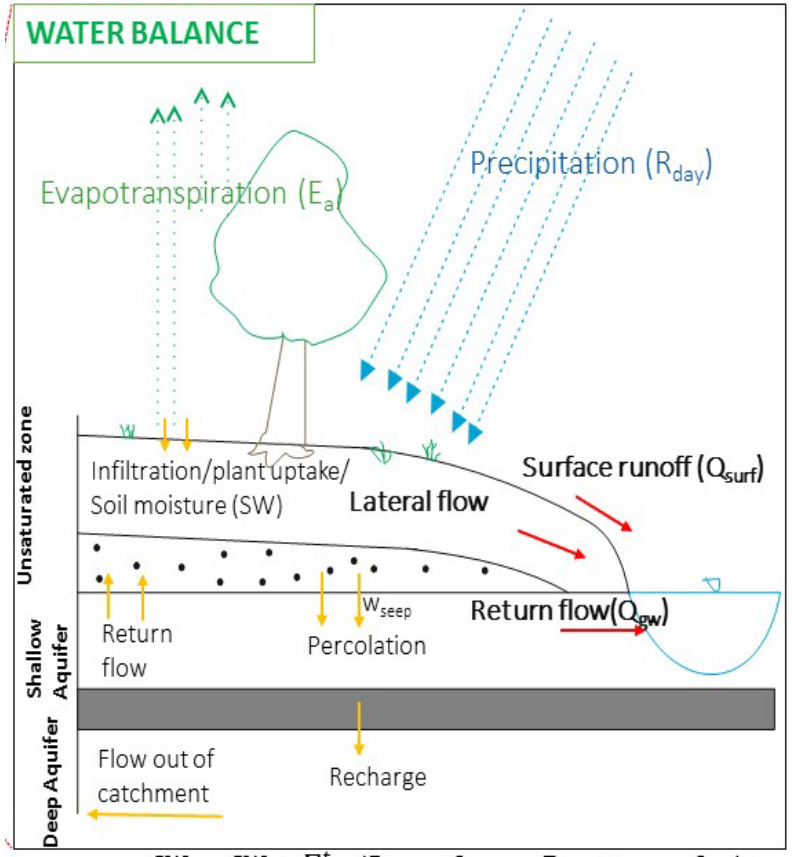
-Variable storage coefficient method

-Muskingum routing method

Sub-daily -Green & Ampt Mein Larson Method: allows a continuous simulation of infiltration processes. Needs sub-daily precipitation as input

Soil water, lateral and baseflow are computed at daily time-step

SWAT MODEL



$$SW_t = SW_0 + \sum_{i=1}^{t}(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw})$$

LAND PHASE

ROUTING PHASE

EROSION AND SEDIMENT CONTENT

ROUTING IN THE CHANNEL:

Daily

- Bagnold (1977): degradation and deposition equations.
- MUSLE (1977): degradation was modified to consider the runoff factor.

Sub-daily

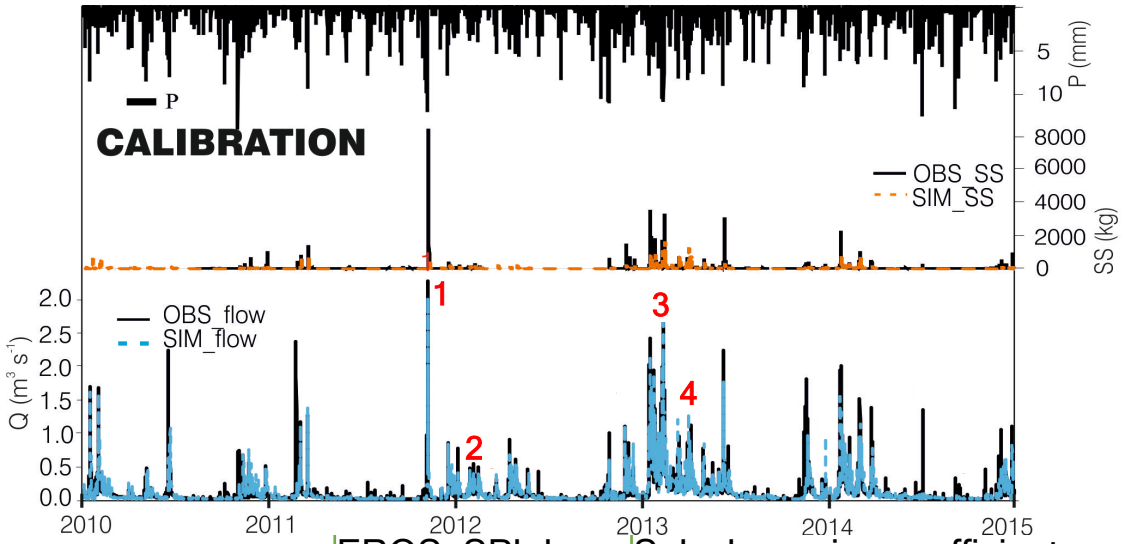
- Bagnold (1977)
- Yang (1996)
- Bownlie (1982)

-SPLASH EROSION: which is important at sub-daily time step (canopy interception) and deposition

Degradation

-SURFACE RUNOFF ROUTING: generates erosion

HOURLY LONG-TERM SIMULATION

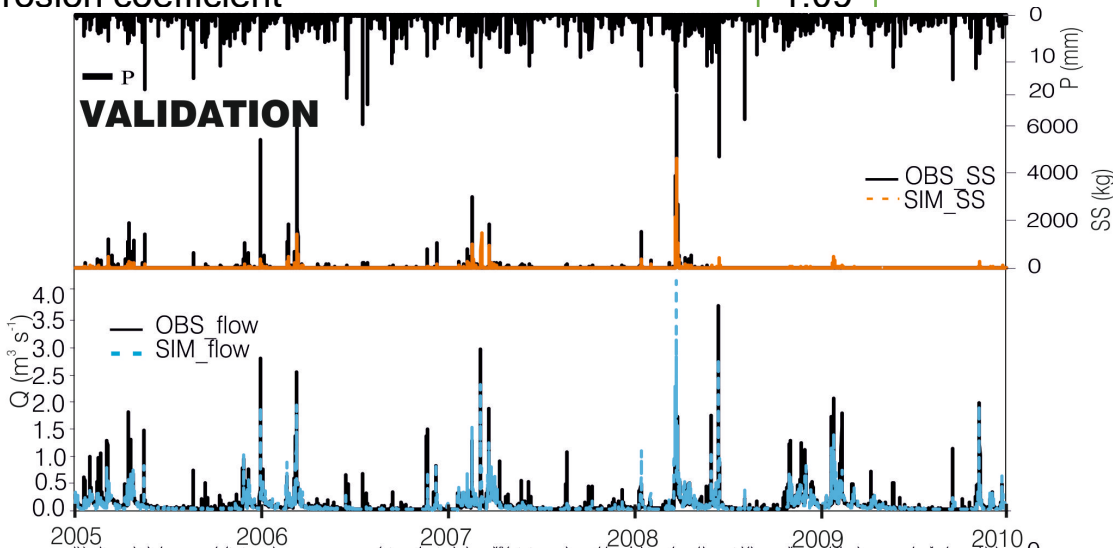


	Calibration (2010-2014)			
	Hourly flow	*Daily flow*	*Hourly sediment*	*Daily sediment*
NSE	***0.71***	***0.79***	*0.24*	*0.37*
R^2	***0.85***	***0.9***	***0.5***	***0.59***
PBIAS	***-12***	***-12***	***-22***	*-23*
RSR	***0.54***	***0.46***	*0.87*	*0.79*

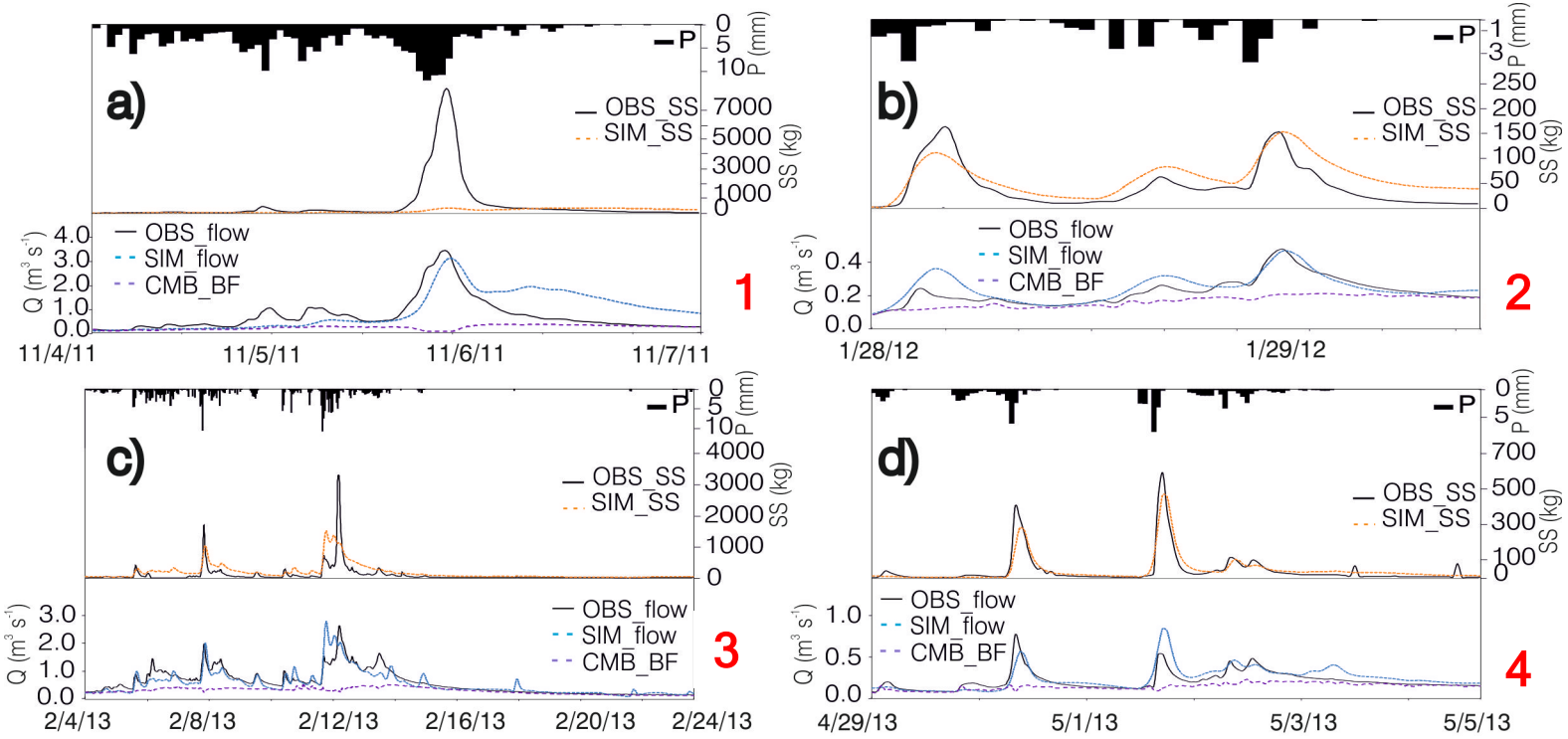
	Value
ion	
cient	1.75
ingum method	5.8
ingum method	5.78
n method	0.18
	1.09

		EROS_SPL.bsn	Splash erosion coefficient
		EROS_EXPO.bsn	Exponer
		C_FACTOR.bsn	Cover ar erosion
		CH_D50.bsn	Median p
		ALPHA_BF.gw	Baseflow
		CANMX.hru	Maximur

	Validation (2005-2009)			
	Hourly flow	*Daily flow*	*Hourly sediment*	*Daily sediment*
NSE	***0.55***	***0.65***	***0.3***	***0.72***
R^2	***0.79***	***0.85***	***0.7***	***0.82***
PBIAS	***5.87***	***6***	***10.88***	***9***
RSR	***0.66***	***0.59***	*0.83*	***0.53***



STORM-EVENTS PERFORMANCE (EVENT-SCALE)



Event	Date	bP7d (mm)	OBS bQ1d (L s^{-1})	IP (mm h^{-1})	Pmax (mm h^{-1})	OBS Qmean (L s^{-1})	SIM Qmean (L s^{-1})	OBS BF/SR	SIM BF/SR	FLOW RSR	FLOW R^2	OBS CSSmean (mg L^{-1})	SIM CSSmean (mg L^{-1})	OBS SST (kg)	SIM SST (kg)	SEDI RSR	SEDI R^2
1	11/4/2011 - 11/8/2011	19.8	20.46	3.7	11.9	649.91	834.12	0.41	0.64	0.77	0.43	105.68	31.85	8430	10940	1.02	0.06
2	1/28/2012 - 1/30/2012	32	90.02	1.0	3.8	223.29	246.14	4.40	3.01	**0.59**	**0.75**	49.67	63.66	1748	2509	**0.61**	**0.75**
3	2/4/2013 - 2/23/2013	47.2	302.1	1.0	10.7	586.85	558.16	1.12	2.23	**0.48**	**0.77**	20.63	52.53	39510	74089	0.75	**0.46**
4	4/29/2013 - 5/4/2013	16.4	91.8	0.6	7.6	214.16	242.60	2.28	3.58	0.74	**0.67**	34.81	35.15	5553	5998	**0.39**	**0.85**

INFLUENCE OF THE PRECIPITATION TIME-STEP

FLOW	2005-2014			
	1H	2H	3H	4H
NSE	0.71	0.64	0.64	0.64
R^2	0.89	0.86	0.85	0.82
PBIAS	-2.29	-14	-12	-14
RSR	0.54	0.6	0.71	0.68

Streamflow is almost no affected by precipitation time-step

SED.	2005-2014			
	1H	2H	3H	4H
NSE	0.48	0.43	0.43	0.41
R^2	0.63	0.68	0.7	0.64
PBIAS	6	17	44	49
RSR	0.76	0.75	0.71	0.71

Sediment load is overestimated as the time step increases

CONCLUSIONS

- The **hourly calibration (2010-2014) and validation** (2005-2009) show (long-term):
  - The **hourly streamflow is simulated correctly** and when these data are gather to **daily time-step the results are** *very good*.
  - The observed and simulated hourly sediment load peaks do not fit well, nevertheless **the amount of sediment is simulated well** -> **daily** the performance is *very good*.

Performance of the timing of sediment transportation should be improved

- As much as higher precipitation time-step the results are worse specially for sediments.

- In the **hourly simulation** of discharge and sediments seems that the antecedent saturation of the catchment plays an important role; **when the saturation is high the discharge simulation performance is better.**


Thank you!
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