Evaluation of the hydrological cycle in the context of climate change

H2020-MSCA-RISE-2018, 2019- 2023 Grant agreement no: 823965

Open Project Day

isardSAT, Barcelona | March 11th, 2022

Evaluation of the hydrological cycle in the context of climate change

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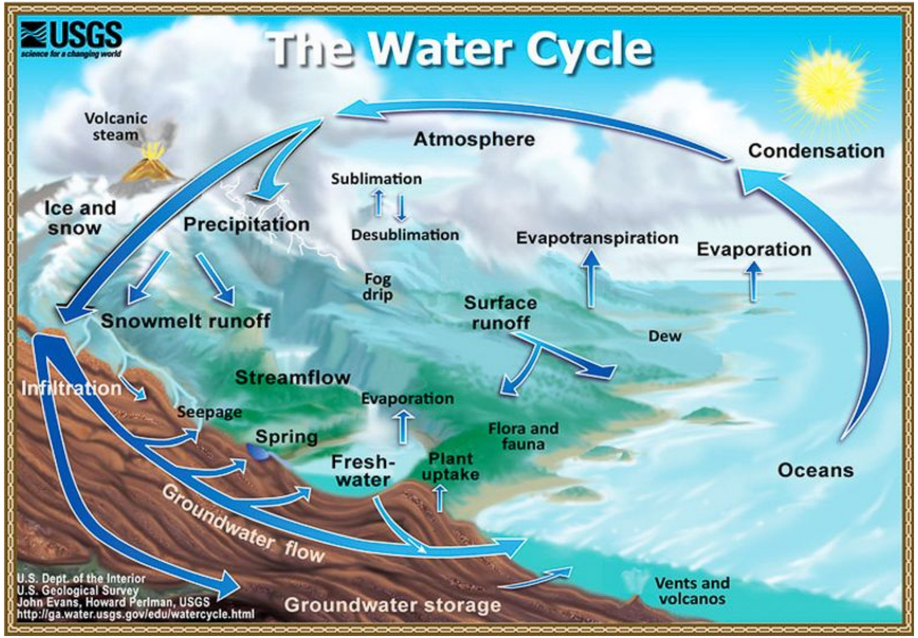
Water cycle

- Most of these processes are difficult to observe and quantify.
- We can measure some of these parameters *in-situ* (scattered points) or with remote sensing (not the complete system).
- Therefore, we need other tools such as hydrological modeling to be able to evaluate the hydrological cycle.



Public Domain. The USGS Water Science School - The Water Cycle
Howard Perlman and John Evans (USGS)

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Study Area: The Pyrenees

PIRAGUA OPCC

The Pyrenees : Natural water towers.
It stretches 415 km from the Atlantic to the Mediterranean.
It is 150 kilometers wide (N-S axis).
Main basins: Ebro, Adour and Garonne

High spatial heterogeneity of precipitation.

- A gradient appears from west to east:
- The transition between the two extremes occurs gradually.

Western valleys:

- The maximum is in autumn (spring's one is secondary).
- Minimum is in summer.

Eastern valleys:

- The maximum is in spring (autumn's one is secondary).
- Minimum is in winter.

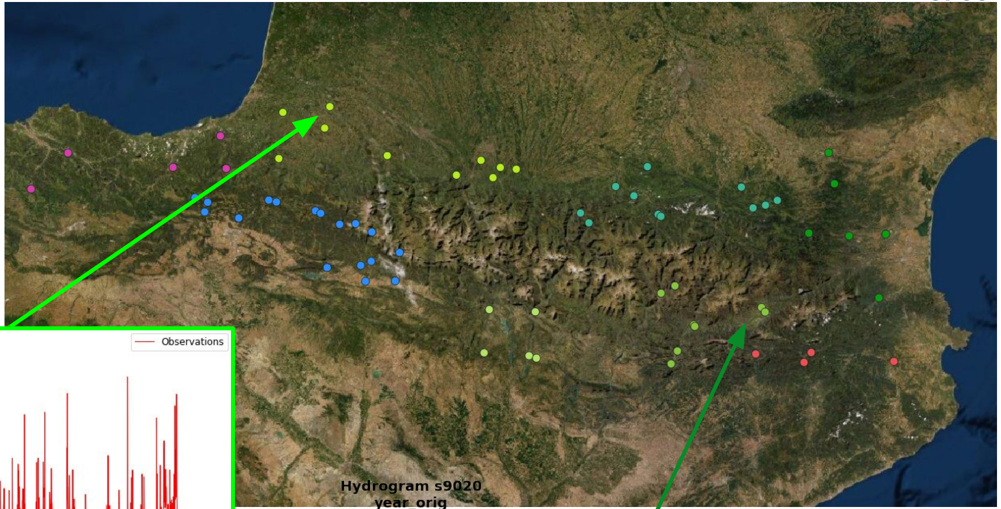
Water surplus. Values above 1000 mm/year near the watershed and on the northern slope.
The adjacent plains lower water balance, even negative values.
Rivers from the Pyrenees are the main source of water resources in surrounding areas:

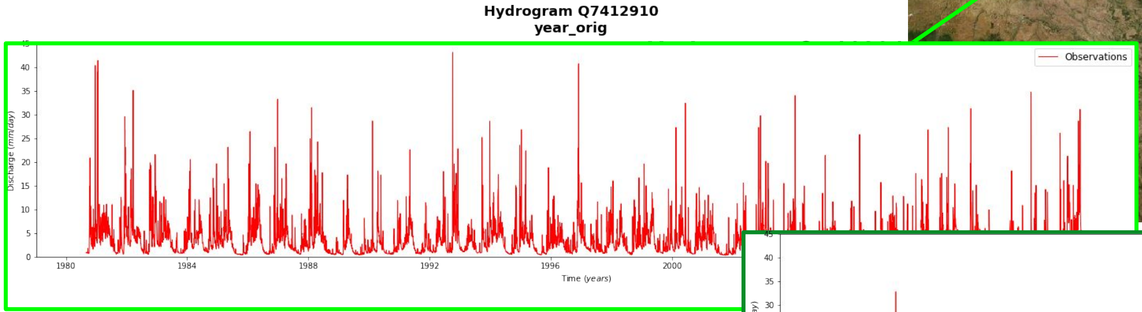
- providing water needs to more than 15 million people
- supplying electricity
- extensive irrigated regions

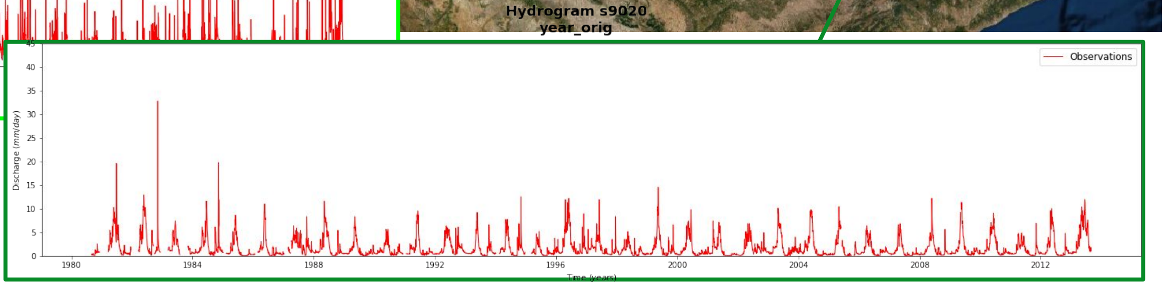
Main precipitation caused by the humid Atlantic air masses.
There is the altitudinal gradient, where precipitation increases as altitude increases.

Observations

We have 67 gauging stations, that provide quality observations of near natural discharge time series from 1980 to 2013



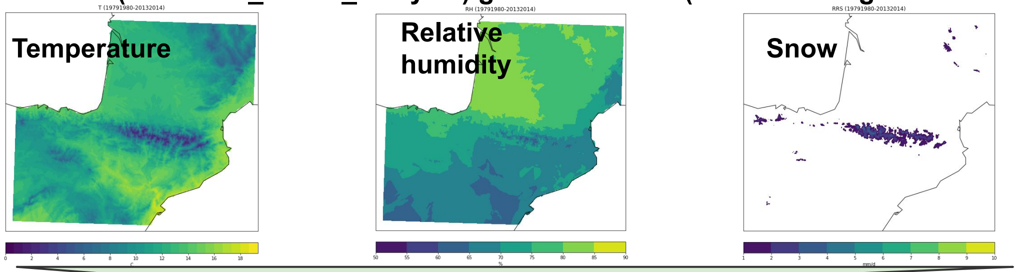




The stations are in a natural or semi-natural regime (not influenced by dams or intensively irrigated areas)

Modelling: SASER

SAFRAN (PIRAGUA_atmos_analysis) gridded dataset (all meteorological variables)



Physically based model.

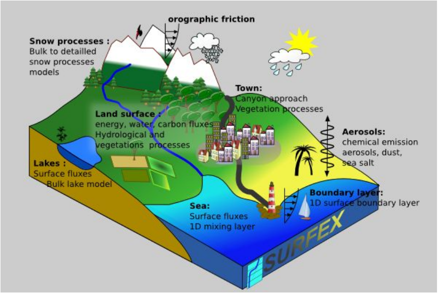
1. **SAFRAN** (PIRAGUA_atmos_analysis)**:** Gridded dataset of all meteorological variables needed to run a LSM. Based on SAFRAN
2. **SURFEX:** Simulation of land-surface fluxes and stocks.
3. **RAPID:** Converts runoff and drainage to streamflow.

Almost no calibration needed!

Performance: Good performance in streamflow simulation (peaks and mean).

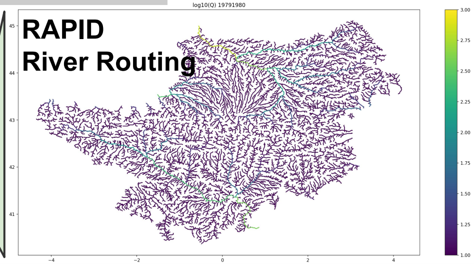
Fluxes
Land evaporation
Runoff
Drainage
...

Stocks
Snowpack
Soil moisture
Interception
...

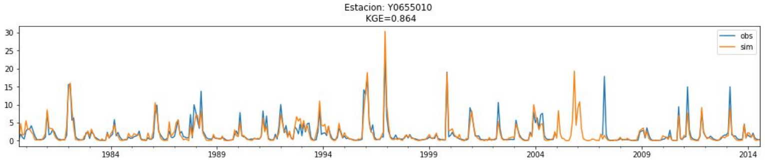


SURFEX Land-Surface Model.

Physically based simulation of the energy and water balances.



Streamflow



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Modelling: SWAT

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Conceptual based semi-distributed model.

- **Operates on a daily time step at the catchment scale.**
- **Has been designed to evaluate the impact of management on water, sediment, and agricultural chemical yields in ungauged catchments**

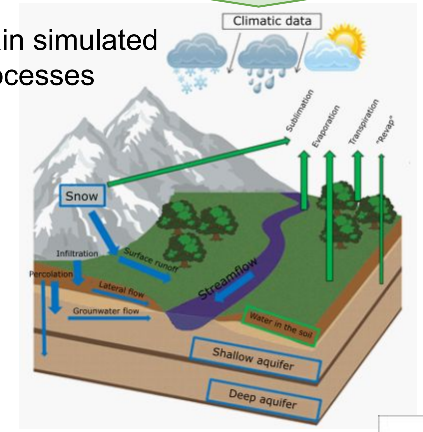
SWAT, as a conceptual model, requires calibration and validation:

Model Initialization	**1980-1985**
Calibration	**1986-2005**
Validation	**2006-2013**

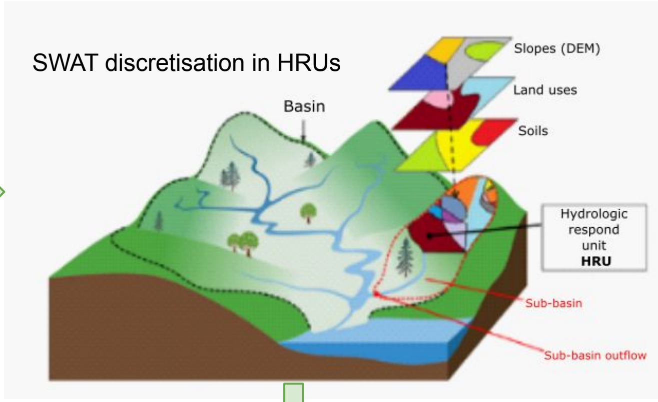
Performance: Good performance in streamflow simulation (peaks and mean).

SAFRAN (PIRAGUA_atmos_analysis) gridded dataset (all meteorological variables)

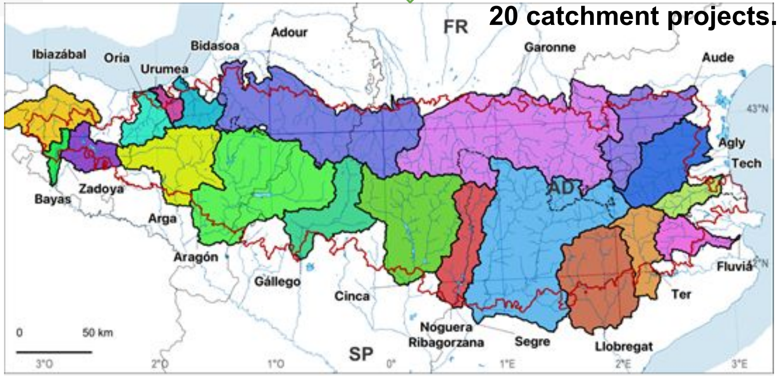
Main simulated processes



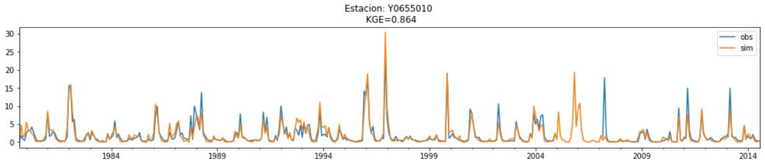
SWAT discretisation in HRUs



20 catchment projects.

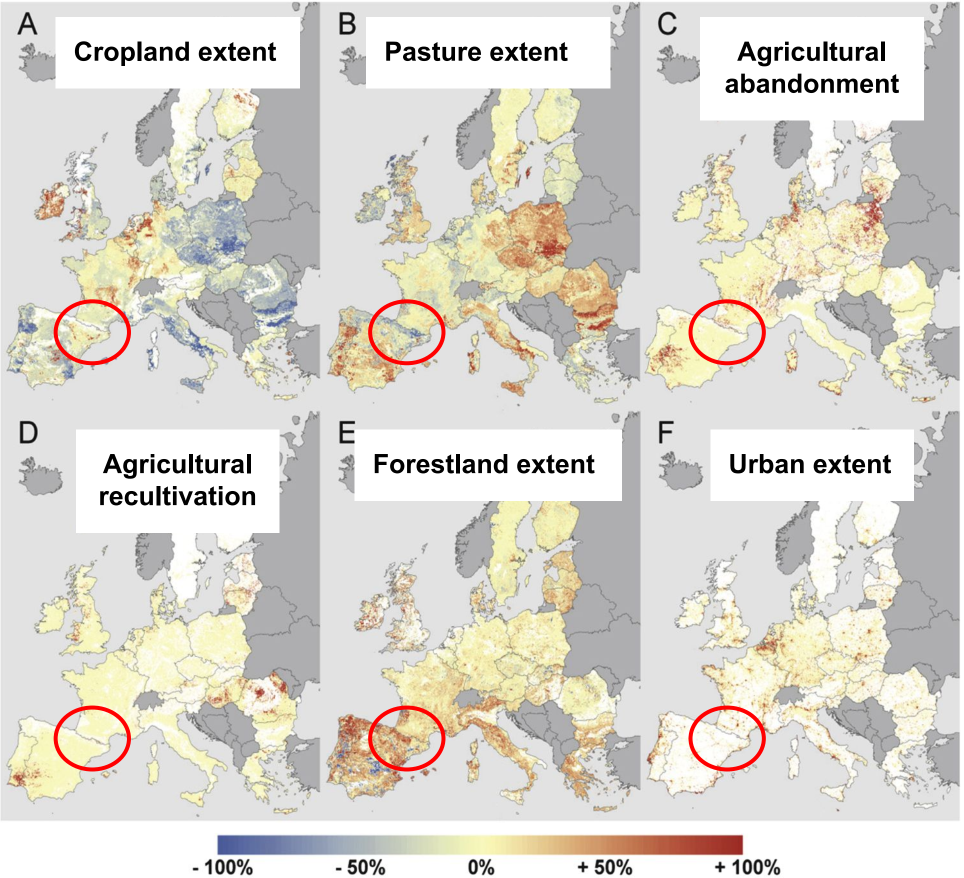


Calibration: Sufi-2 algorithm



Streamflow

Land Use



In the models, land use does not change. Thus, the streamflow changes due to changes in land use will be reflected in the observations but not in the simulated streamflow.

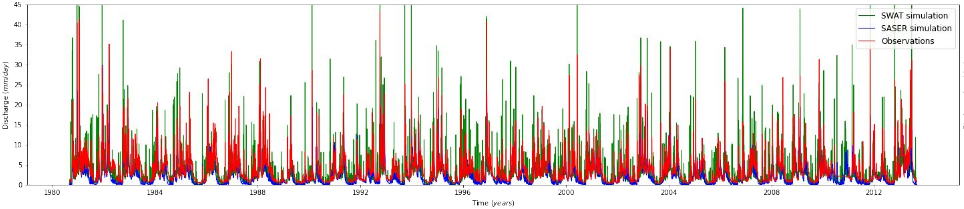
Spatial patterns of changes in the area of broad land-use categories in Europe.

Changes refer to the period 1990–2006

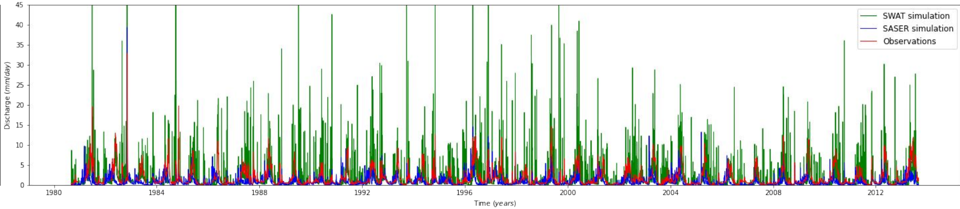
Tobias Kuemmerle et al. (2016)

Descriptive statistics

Hydrogram Q7412910
year_orig



Hydrogram s9020
year_orig



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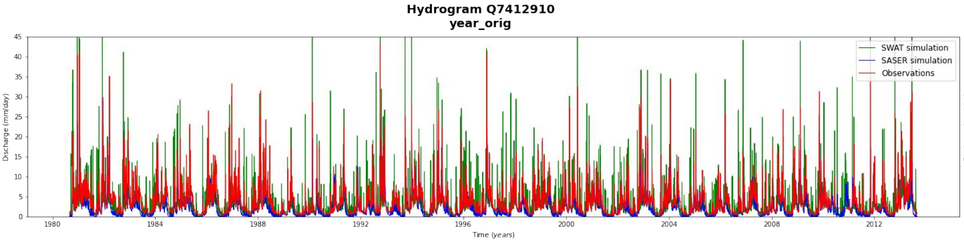
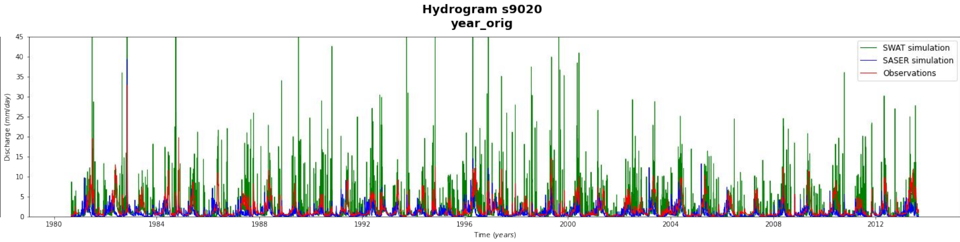
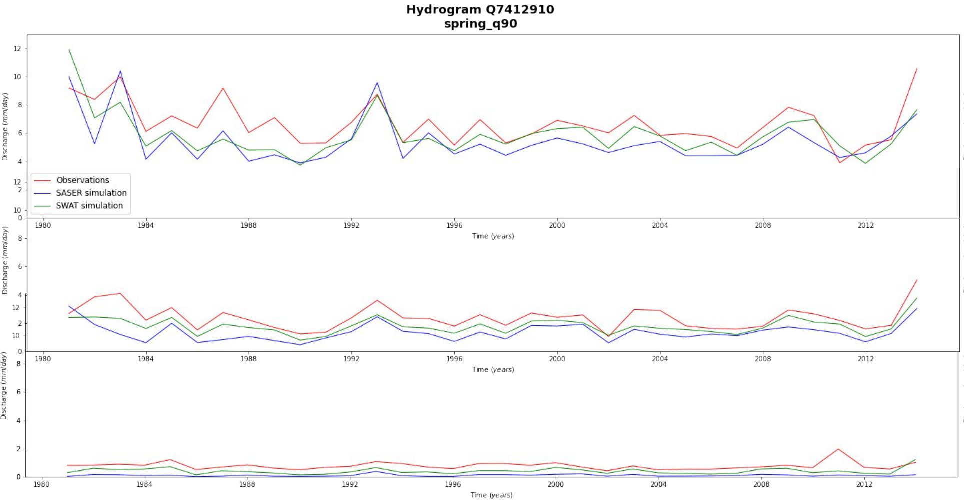
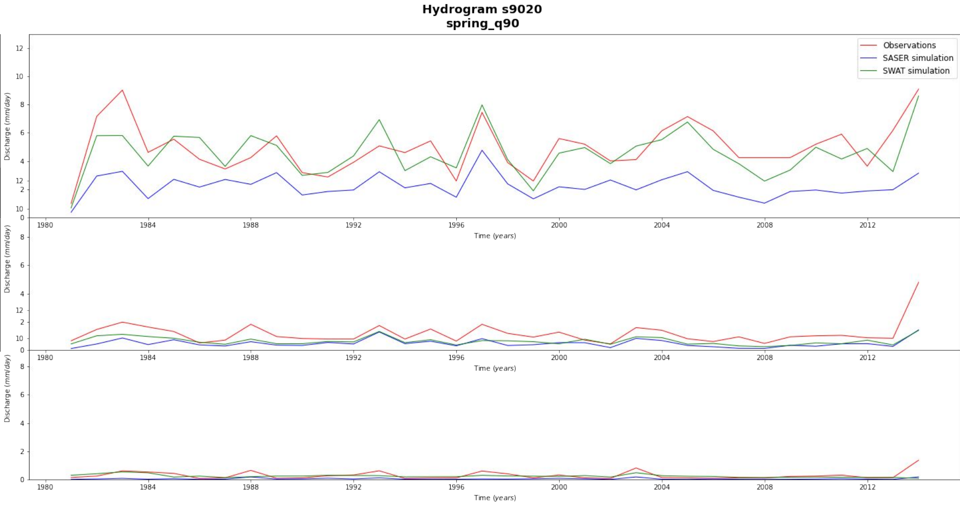




Monthly and seasonal descriptive statistics: *(mean, Q10, Q50, Q90,....)* for 33 year period: **1980-2013**





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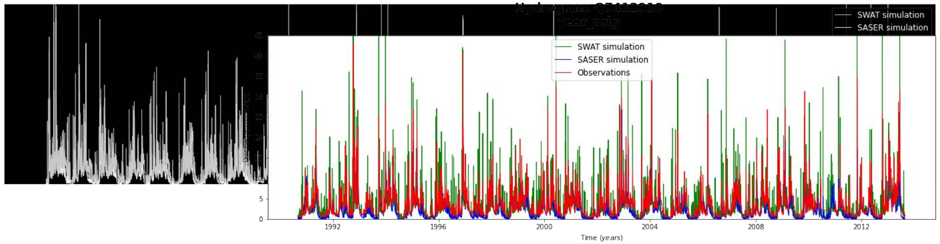
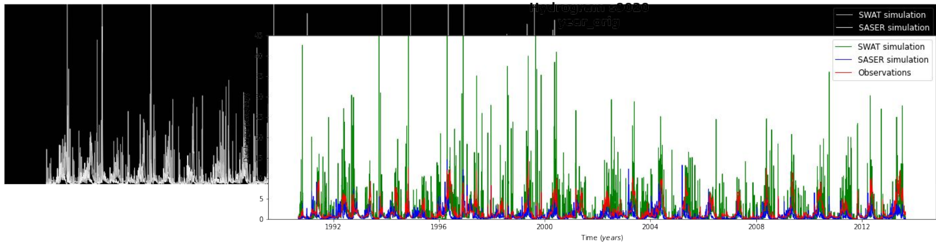
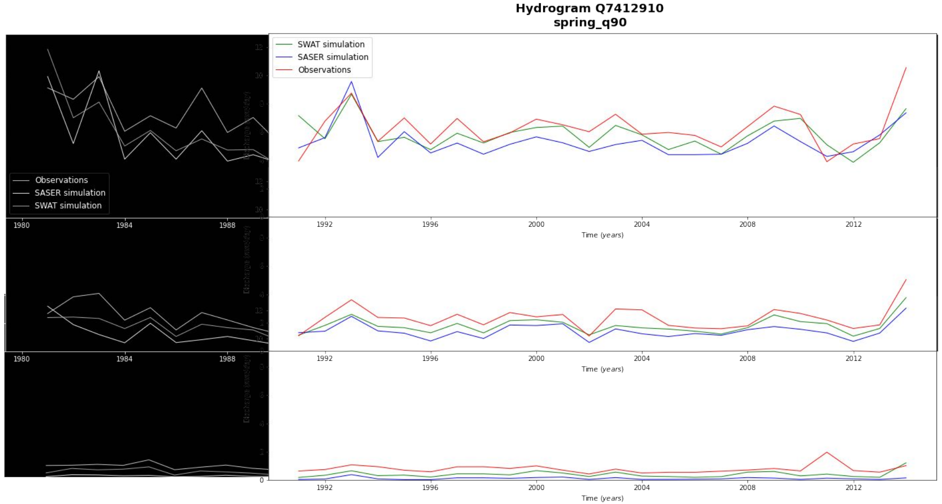
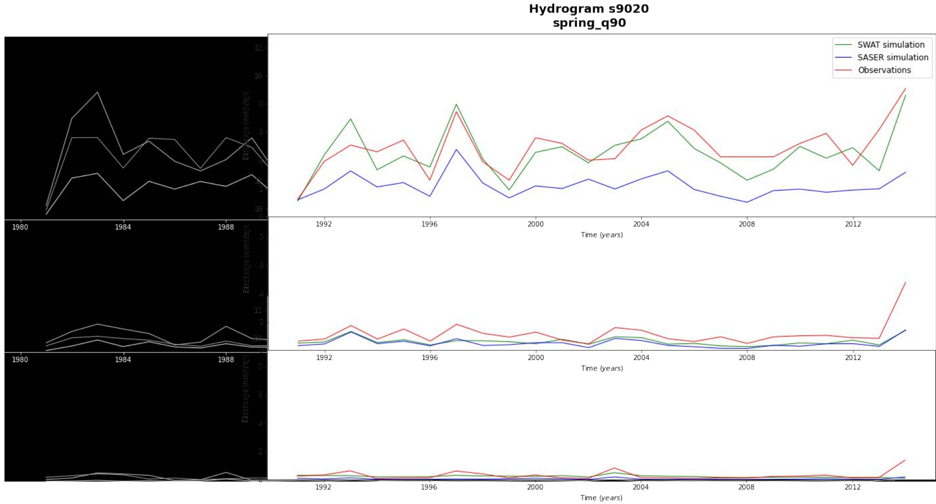




Monthly and seasonal descriptive statistics: *(mean, Q10, Q50, Q90,....)* for 23 year period: **1990-2013**





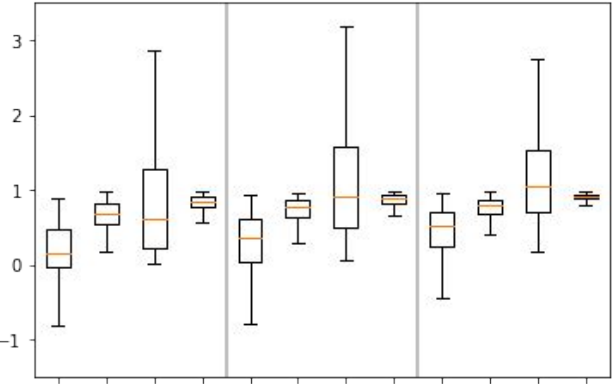
Evaluating simulations

We used the Kling-Gupta efficiency (KGE) test as a goodness-of-fit test to evaluate the simulations

α: discharge variability
β: bias between simulated and observed.
r_s: discharge dynamics.
KGE = 1 - sqrt{(β-1)^2+(α-1)^2+(r_s-1)^2} *Pool et al. (2018)*

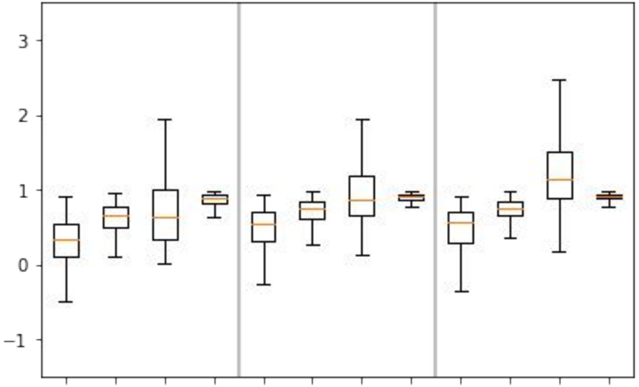
Both models give good KGE values (mostly KGE>-0.41), being SWAT's higher than SASER's. However, it should be noted, that SWAT has been calibrated for this purpose.

KGE test Observations/SURFEX



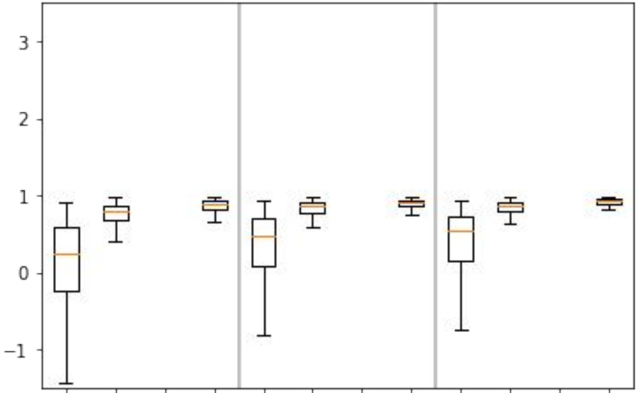
KGE r_s β α KGE r_s β α KGE r_s β α

KGE test Observations/SWAT



KGE r_s β α KGE r_s β α KGE r_s β α

KGE test SURFEX/SWAT



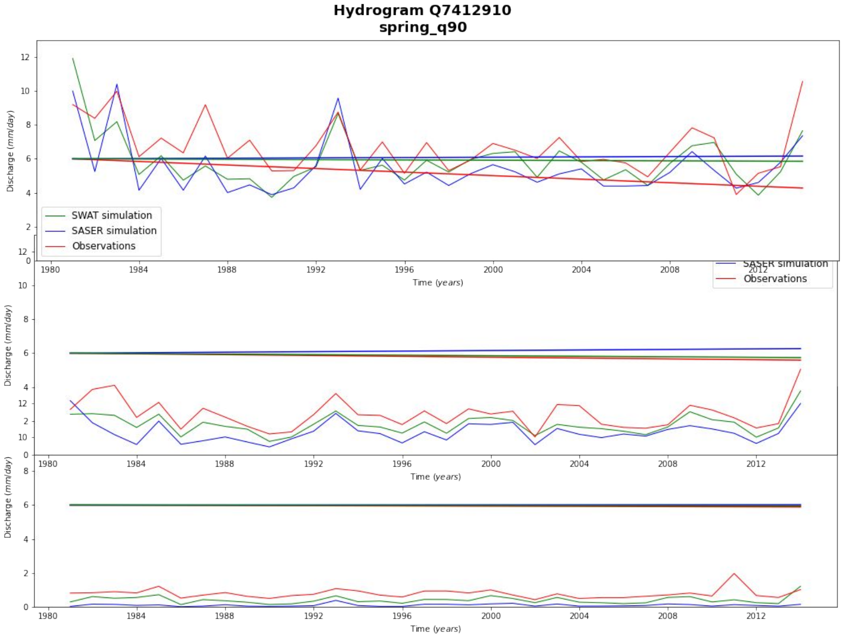
KGE r_s β α KGE r_s β α KGE r_s β α

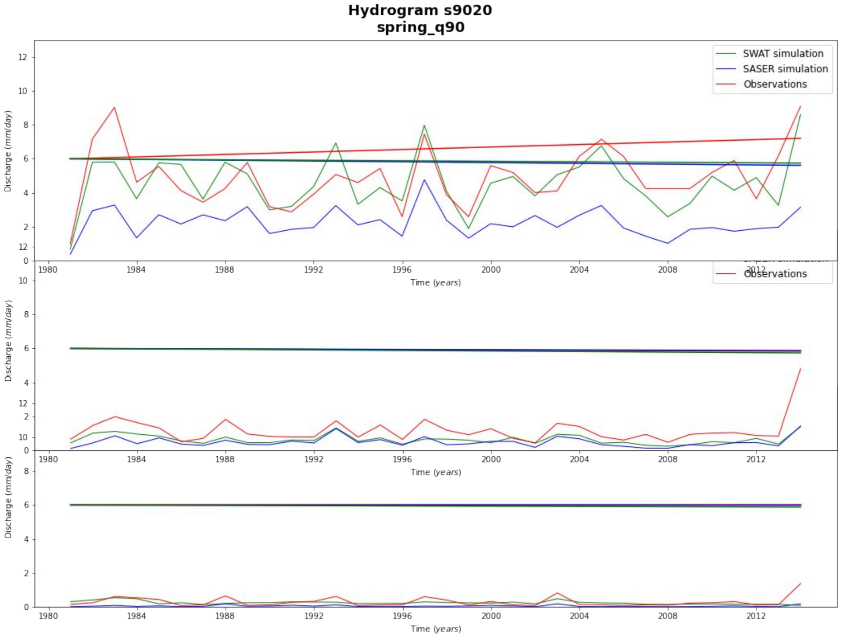
Trend Analysis

- **Mann-Kendall test**: to analyze for consistently in increasing or decreasing trends
- **Sen's slope**: to compute the slope of the trend

Sometimes, prewhitening the series, when there is autocorrelation, is needed.

We can see that trends in Q10 are more or less flat, but differences increase in Q90, even a change of sign in the trend can be observed.





Trend Analysis

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Binary classification: sign of the trend

- Contingency tables
- Scores

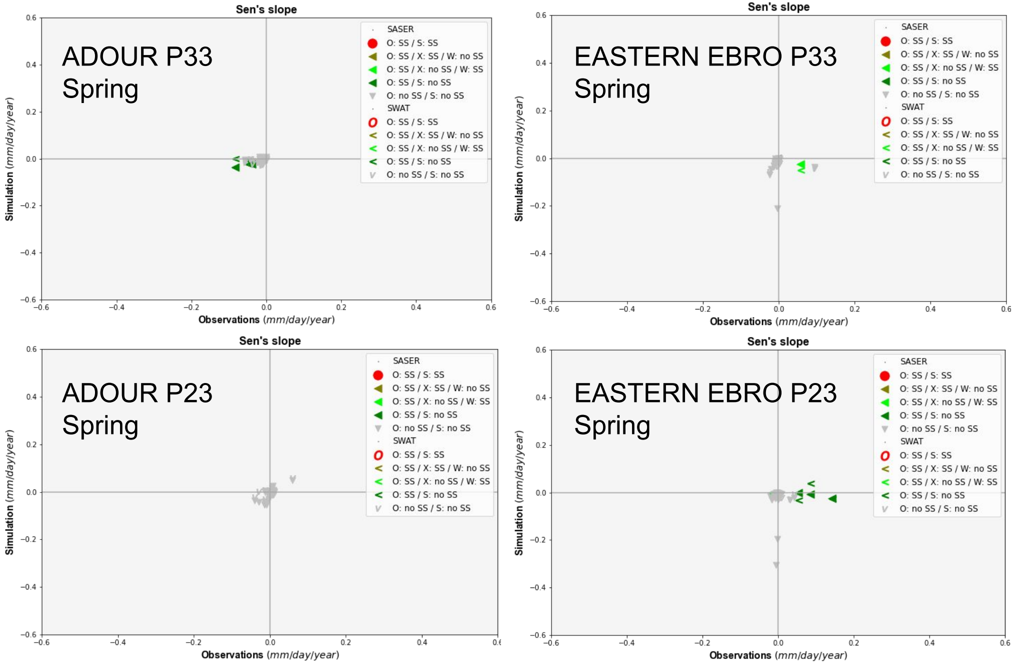
ADOUR

		OBSERVATIONS +	OBSERVATIONS -				+	-	
SASER	+	461	213	674	SWAT	+	423	170	593
	-	175	570	745		-	213	620	833
		636	783	1419			636	790	1426
Accuracy		0.73					0.73		
F1 Score		0.70					0.69		
MCC		0.45					0.45		
Kappa		0.45					0.45		

EBRO_E

		OBSERVATIONS +	OBSERVATIONS -				+	-	
SASER	+	208	115	323	SWAT	+	152	74	226
	-	269	656	925		-	325	698	1023
		477	771	1248			477	772	1249
Accuracy		0.69					0.68		
F1 Score		0.52					0.43		
MCC		0.32					0.28		
Kappa		0.31					0.26		

Sen's slope visualization



Trend Analysis

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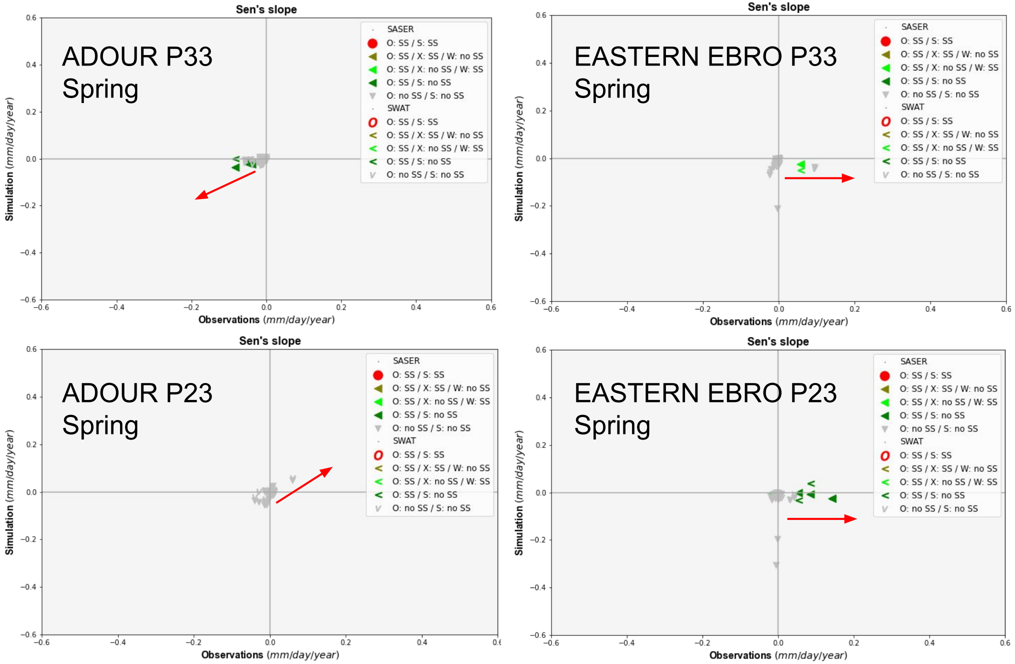
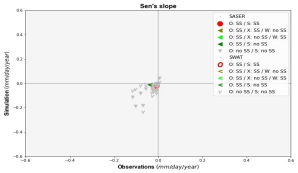
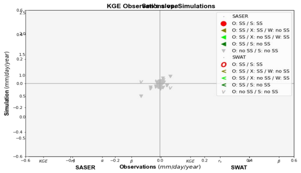
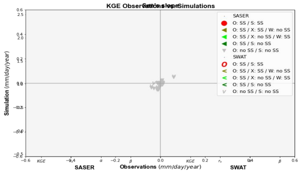
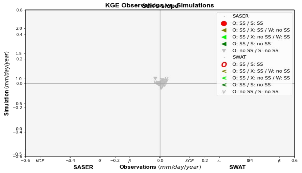
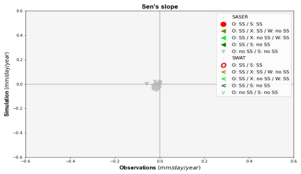
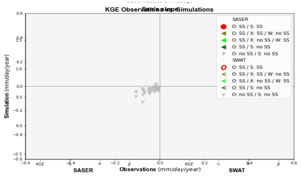
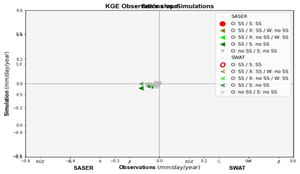
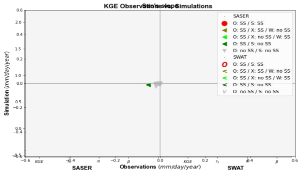


Trend Analysis Conclusions

ADOUR

	Autumn	Winter	Spring	Summer
23 years				
33 years				

The 23 year time series:

- Decrease in Autumn
- Other season equal.

We attribute this decrease to climate change

The 33 year time serie:

- not clear trends in sim.
- decrease in spring and summer in obs.

We attribute this decrease to land use changes

Trend Analysis Conclusions

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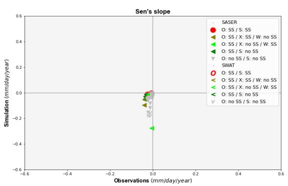
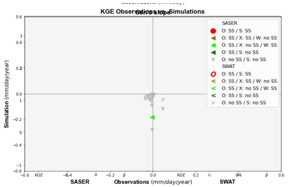
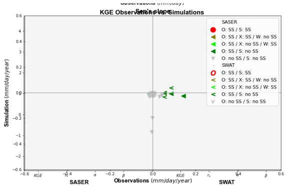
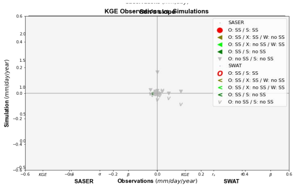
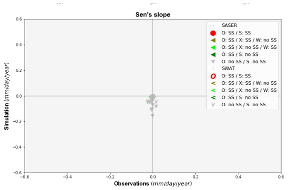
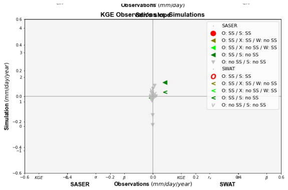
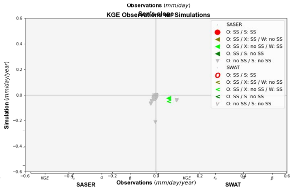
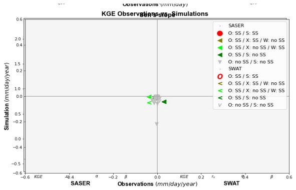
Eastern EBRO

Autumn | Winter | Spring | Summer

23 years

33 years

The 23 year time series:

- Decrease in Autumn
- Spring: Not trend in sim, but increase in obs.

We attribute these changes to climate, but not clear.

The 33 year time serie:

- Increase in winter and spring.

We attribute this increase to climate change, but not clear.

Conclusions and next steps

WE ARE STILL WORKING ON THE RESULTS !!!

- We observe :
  - more streamflow in the northern slope than in southern slope of Pyrenees (no surprise)
  - more streamflow in the western Pyrenees than in the eastern Pyrenees (no surprise)
- We obtained very different values from simulations, showing a great uncertainty. Concluding that it is good to use different models and approaches.
- It seems to be:
  - In the longer period (33 years) there are more trends in observations than in simulations.
  - In the shorter period (23 years) the trends in observations and in the simulations are more similar.

One explanation could be that, during the 1980s, climate change was not as marked as changes in land use.
On the other hand, climate change was already noticeable in the 1990s.

We are working on:

- analyzing the data

Next:

- Compare the hydrological cycle modeled by different scenarios for the historical period and for future climate predictions.

Thank you!

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Tis